OR VEHICLES
FOR
USINESS PURPOSES

A. J. WALLIS-TAYLER

MOTOR VEHICLES

FOR

BUSINESS PURPOSES

A PRACTICAL HANDBOOK
FOR THOSE INTERESTED IN THE TRANSPORT
OF PASSENGERS AND GOODS

BY

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"MOTOR CARS OR POWER CARRIAGES FOR COMMON ROADS," "MODERN CYCLES," "THE CONSTRUCTION OF ROADS AND STREETS," "AERIAL OR WIRE-ROPE TRAMWAYS," "REFRIGERATING AND ICE-MAKING MACHINERY," "REFRIGERATION, COLD STORAGE, AND ICE-MAKING," "THE POCKET-BOOK OF REFRIGERATION," "TEA MACHINERY AND TEA FACTORIES," "THE SANITARY ARRANGEMENT OF DWELLING HOUSES," "SUGAR MACHINERY," "BEARINGS AND LUBRICATION," ETC. ETC.

WITH 134 ILLUSTRATIONS

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Transport.

PREFACE

THE motor or self-propelled vehicle, as adapted for business purposes, may now be said to have arrived at a state of perfection, and its commercial utility to have been sufficiently proved by actual practical working to place its future on an assured basis.

Advantages to be derived from the use of the self-propelled vehicle are: greater speed and economy in transporting heavy loads than with horse vehicles, and consequently saving of time and money; a large reduction of labour and expense as compared with the driving and care of horses and vehicles, provision of stabling, etc.; an improved sanitary condition of the roads and streets, and of towns and cities generally; economy in road maintenance; and additional safety.

It is not too much to say, indeed, that within a few years mechanically propelled vehicles for business purposes, and especially heavy-freight vehicles, will have practically a monopoly on the roads in the transport of both passengers and goods.

Under these circumstances, a book containing within a moderate compass and in an accessible form such information as will enable intending purchasers or users of motor vehicles to ascertain the respective merits of the various systems, and their adaptability to special

requirements, should fulfil a useful purpose. This want it is hoped that the present volume will help to supply. For more extended description of many of the commercial vehicles here mentioned than has been found practicable, the reader is referred to the articles which have appeared in the technical press.

During the past two years the Author contributed to the *Automobile Commercial Vehicle Review*, now published weekly as *The Industrial Motor Review*, a series of articles on "Self-Propelled Vehicles for Business Purposes," which (through the kind permission of the Editor) he has been enabled to incorporate in a modified and amplified form in the present volume. Chapters have also been added dealing with self-propelled vehicles for municipal purposes; miscellaneous types of motor vehicles, including motor railway carriages; and the cost of running and maintenance.

Thanks are also due to various manufacturers and others for their courtesy in furnishing much valuable information, and in many cases photographs and drawings for purposes of illustration.

It is particularly desired to point out that where descriptions of machines of various makers have been omitted, such omissions are in no way to be attributed to any inferiority in the construction of these vehicles, but solely to the fact that the space at command has of necessity limited the descriptions to typical examples of each system.

A. J. WALLIS-TAYLER.

SUTTON, SURREY.
July, 1905.

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FUTURE OF THE BUSINESS MOTOR VEHICLE

IN the opinion of all those well qualified to judge, the heavy motor vehicle has before it a most important future, and there can be but little doubt that the self-propelled vehicle will in time supersede the horse for the transport of freight. Indeed, for the conveyance of heavy loads of passengers and goods, which is the more legitimate field of mechanical locomotion—both about the streets of towns and cities and in the country—the motor-driven vehicle will, it may safely be predicted, in a very few years' time hold a practical monopoly.

The objections inherent to tramways, and the impossibility of establishing them in many districts, have raised a problem the satisfactory solution of which has been found in the railless electric line.

This system, which consists of electric motor-driven vehicles receiving current from overhead wires, and running on ordinary roads, is suitable for both passenger and goods traffic, and may at some future time go far towards, if not altogether, abolishing tram lines.

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For long distances the cheapest system of land carriage is, and will, undoubtedly be found to be the railway. At short distances, however, the terminal charges form so heavy a proportion of the total cost, that this method of transport is rendered impracticable commercially, so far as goods are concerned. It is here that the heavy motor waggon or freight vehicle should more especially be brought into service, and being able to move from any one point to any other point, and thus to enable breaking bulk and carriage during the journey to be avoided, goods might be carried by this means at rates that would be impossible on railways for short distances.

CLASSES OF BUSINESS MOTOR VEHICLES

Self-propelled vehicles for business purposes or commercial use may be conveniently divided into two main classes, that is to say, first, those adapted for the conveyance of passengers, and, second, those adapted for the carriage of goods.

Each of these main or principal classes may, for additional facility of description, be again subdivided into two kinds of vehicles, viz. light and heavy.

In the first class, the light type of vehicle are those adapted to carry a small number of passengers, such as cabs or small omnibuses plying for public hire. The heavy type comprises such vehicles as large omnibuses and the like, carrying passengers on fixed routes or otherwise.

In the second class, the light type of vehicles includes all those suitable for tradesmen for the quick delivery of goods; and the heavy type such vehicles as are adapted for the transport of freight or heavy loads of goods at comparatively slow speeds.

ADVANTAGES OF BUSINESS MOTOR VEHICLES

Attention may here be appropriately drawn to the great and many advantages which motor vehicles of both the light and heavy types possess for the purposes indicated above.

In the case of the lighter type of motor vehicle, mention may be made of the following: Greater rapidity of delivery by reason of quicker transit, and greater rapidity of stopping and starting,

and consequently fewer vehicles required. Saving in rent of premises as compared with horses and carts. Fewer hands wanted than in the case of stables, when not only have the vehicles to be cleaned but also the horses. No outlay for running except for fuel and sundries when actually on the road, whilst a horse is continually consuming food, and therefore requiring outlay whether working or not. Greater immunity from accidents, as has been shown by practical working. And finally, that motor vehicles are far more sanitary, not likely to be non-available when wanted, as horses frequently are through sickness or being tired, and not dependent to a great extent upon the weather, as is the case with horses.

The above advantages apply equally to the case of motor vehicles adapted for heavy duty, and, in addition, motor vehicles of this class possess such special qualifications for the conveyance of goods for comparatively long distances, that it would be entirely impossible for animal traction of any kind to compete with them commercially with success.

PROPELLING POWERS OR PRIME MOVERS FOR BUSINESS MOTOR VEHICLES

As regards the propelling agencies which have been experimented with up to the present time, it may be safely asserted that almost every known motive power has been tried. Steam was successfully employed as early as 1820, and the motor vehicle would long ago have been perfected in this country had not the art been stifled in its early infancy by enactments, the passing of which were secured by the intrigues of interested parties, fearful lest their monopolies might be injured, and totally regardless of the public welfare when they imagined their private pockets might suffer.

These restrictions would probably be still in force if the enlightened views of our present sovereign King Edward VII. and the example of what foreign nations were doing had not supported the desire of the British people for their removal, and for the according to those using mechanically propelled vehicles of the same liberty on the public highways as is possessed by those employing vehicles hauled by animal traction. This influence was successful in securing emancipation from these absurd and

galling restrictions. But meanwhile the labours of the eminent and enterprising engineers in this country of eighty-five years ago had been, of course, frustrated, and foreigners had been permitted to begin where our engineers had been forced to stop, and to get ahead of us in the art.

Following on steam, the next experiments were in the line of internal combustion or oil engines, and by electrically driven vehicles, compressed air, carbonic acid, etc.

As it is only purposed, however, to deal with the present types of commercially successful vehicles, the sources of power here dealt with will be confined to steam or external combustion engines, oil or internal combustion engines, and electricity.

For light motor vehicles for business purposes, in which class are to be included all those intended for the rapid conveyance of limited numbers of passengers, or the delivery of comparatively light loads of goods about our cities and towns, all three of the above propelling agencies are suitable, and the same remark also applies to heavy motor vehicles intended for the transport of a considerable number of passengers, such as motor omnibuses and the like.

In the case of heavy freight vehicles, however, where an abundant supply of power is required, internal combustion or explosive motors have not as yet been found in practical working to give quite such favourable results.

The reason for this is not far to seek. The great weight of a self-propelled waggon and of its load, and the peculiar manner in which it operates, demands the employment of not only a motor of large power, but also of a flexible one, so that the natural action of the horse may, as far as possible, be imitated. The horse, on an emergency, is capable of exerting power equal to what we would term 15 horse-power or even more, but when the necessity for this effort ceases the horse only continues to exert sufficient power to haul the vehicle on the smoother surface. This the steam-engine can do by reason of its flexibility, but on the contrary the internal combustion or explosion engine, by reason of its construction, is of necessity run at a constant speed, and is non-reversible, and these defects are only imperfectly eliminated by the speed-changing devices applied, which consist mainly of such elements as spur and bevel gears, belts, chains, shifting wheels, friction wheels, pulleys with expanding faces, or

various combinations of some of these devices with brakes and clutches. Attempts have likewise been made to employ hydraulic and electric combinations for the purpose.

Needless to say, these speed-changing devices, whatever may be their success in the case of light or comparatively light vehicles, are more or less unsuitable for heavy freight vehicles, clutch and shifting gear wheels being in this case, owing to the impact of the moving masses, liable to frequently give rise to very serious trouble when being constantly brought into use to adapt the engine, which is running at a constant speed, to the speed requirements of the motor waggon wheels, which are ever changing.

An internal combustion engine, besides, will not start with a load on, and even when it is running is dependent for its action on the even influx of the explosive mixture, and is liable to come to a sudden dead stop without any previous warning, should its capacity be at any time suddenly overtaxed. Again, the oil-motor is greatly influenced by the weather, owing to the effect exerted upon the carburettor by the atmosphere. The pounding of the large engine is liable to injure the frame of the vehicle. A certain amount of risk of explosion and fire exists, and there is the possibility of injury to the goods carried, when they consist of articles of a perishable nature and foodstuffs, by reason of the far from pleasant odour of the oil and exhaust.

In short, although possessing many obvious advantages as a motive power for light and comparatively light motor vehicles, the use of internal combustion engines of large power on heavy motor waggons has not hitherto been attended with that amount of success which would seem to warrant the use of this type of motor in preference to the steam-engine, at least not until such time as an internal combustion engine has been designed which will be capable of varying its speed through a wide range, and will be likewise satisfactory in its operation in other respects. Theoretically, of course, the internal combustion engine is the most economical.

CHAPTER II

RESISTANCE TO TRACTION ON COMMON ROADS

Rolling Resistance—Traction on Rising Gradients and Distribution of Load on Wheels—Width of Tyres—Speed and Suspension—General Result of Early Experiments in Resistance to Traction on Common Roads—Sir John Macneil's Experiments—Resistance due to Rising Gradients—Table calculated from Macneil's formulæ showing Force required to draw Vehicles over Inclined Roads—Recent Experiments on Traction on Common Roads—Table compiled from recent Tests giving Tractive Force required to haul a Load of One Ton on Various Grades, and Equivalent Length of each Mile of Grade in Miles of Level Road—Resistance due to the Air—Resistance due to Starting—Adhesive Power of Motor Vehicles

BEFORE proceeding to give specific descriptions and illustrations of typical examples of self-propelled vehicles adapted for business purposes, in the order of the classification that has been already indicated, it has been thought desirable to deal at as great length as the space at command will admit of, with the subject of resistance to traction on common roads.

This subject is one of paramount importance, inasmuch as the propulsion, and the maintenance of the speed of motion, of all wheeled vehicles can obviously only be effected by overcoming the various resistances by which such propulsion is opposed.

These resistances are forces which are variable inversely to the force of traction expended.

When moving slowly forward in a straight line, at a constant rate of speed, the force of propulsion will be equal to the resistance. The latter comprises the following elements: Resistance to rolling on the road surface, commonly denominated rolling friction; resistance due to the friction of the wheels rotating on their axles; and resistance due to wind pressure.

To the above must be added:—

In starting, the resistance due to inertia, which is the property possessed by any body of maintaining its condition of rest or motion if not acted upon by some force. This is the first law of motion, which is frequently spoken of as the law of inertia.

Whilst travelling, the resistance due to weight, when passing over gradients, which resistance is of a positive or negative quality in accordance with the direction of motion, viz. whether the vehicle is going up or down.

In running round curves resistance of a special nature is produced, the value of which augments in a ratio corresponding to the diminution of the radii of the curves.

All the above-mentioned resistances are common to all wheeled vehicles, being due to their traction or propulsion on any road surface. In the case of mechanically propelled vehicles, it is to be observed that there is yet another source of resistance to be taken into account, to wit, that arising from the use of the engines or motors, of whatever be their description, for purposes of propulsion. This latter element, however, may be dismissed for the present, and those resistances to traction which wheeled vehicles have to overcome on a common road be dealt with seriatim.

ROLLING RESISTANCE

Rolling resistance—or, as it is commonly called, rolling friction—is that due to the resistance offered by the circumference of a wheel to the power by which it is propelled.

This class of resistance is due to the greater or lesser inequalities of the surface in the immediate vicinity of the points of contact of the wheels of the vehicle with this surface, and which inequalities form obstacles that must be overcome, thereby giving rise to a resistance that consumes a proportion of the propelling power corresponding to the extent of the inequalities.

This proposition will be made clear by the diagram Fig. 1, in which a is a cylinder having a radius ρ, and which cylinder a is standing on a horizontal plane surface $b\, b^1$. Laterally and concentrically upon the axis of the cylinder a is fixed, as indicated on the diagram, a small pulley c having a radius y.

If tangentially to the pulley c a force d be applied vertically, such as a weight suspended on the end of a fine cord wound on

the pulley c, it can then be demonstrated that it is possible to gradually increase the value of the force d up to a point just beyond which the equilibrium of the cylinder a will be upset, and it will be caused to move or travel in the direction indicated by the arrow. It will be seen that the cylinder a is subjected to three forces, that is to say, the weight e of the cylinder a, the vertical force d, and that resulting from the sum x of the resistances offered by the plane surface bb^1. This latter force, which is necessarily

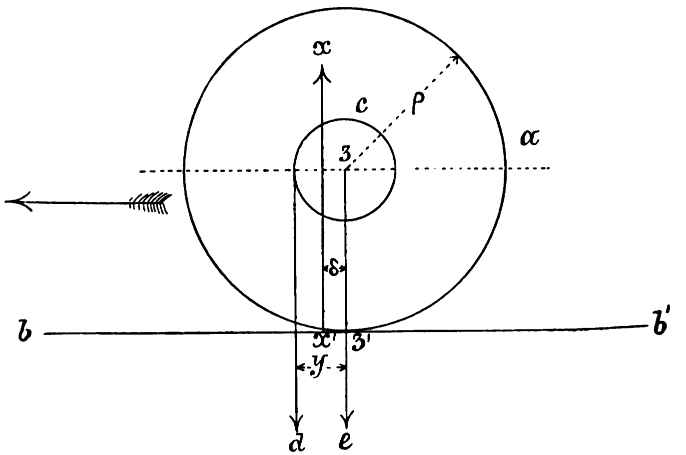

Fig. 1.—Diagram showing rolling resistance on plane surface, power applied vertically.

a vertical one, will equal $e + d$, as, however, the latter quantity is not sufficient to maintain the equilibrium of the cylinder a, and as we have just seen that the forces are so balanced that the cylinder a is in a state of equilibrium, it follows, then, that the sum of the forces e, d, x, round the horizontal axis projected to z^1, is nil.

From the above we find that—

$$dy = x\delta = z$$

$$\delta = \frac{dy}{x} = \frac{dy}{e + d}$$

that is to say, that the product x of the resistances offered by the plane surface bb^1 must pass through a point x^1 beyond the vertical

axial line zz^1, and on that side of the latter to which the cylinder a tends to roll upon the plane surface bb^1.

The resistance offered to the cylinder a rolling on the plane surface bb^1 is equal to the maximum force applied at d that may be necessary to overcome the state of equilibrium of the cylinder a and to cause it to roll on the plane surface bb^1 in the direction of the arrow. Or, to be more accurate, the above-mentioned resistance is measured by the product dy, because d and y will vary in an inverse ratio the one from the other, whilst all the other factors remain constant.

The above considerations also apply when the application of the force d is made in a horizontal instead of a vertical direction. In this case the product x of the resistances offered by the plane surface bb^1 will be oblique respectively to this plane surface as the product of the forces d and e in the diagram Fig. 2. Indicating by g the component of y parallel to the plane surface bb^1, and by x the line normal to the same plane, then on the instant at which the state of equilibrium of the cylinder a is on the point of being interrupted, we have the two following equations:—

$$e - x = z$$

and—

$$d - g = z$$

to which equations must be also added the following equation of the turning movements around the point z^1:—

$$d(y + \rho) = x\delta$$

from which is obtained—

$$\delta = \frac{d(y + \rho)}{z} = \frac{d(y + \rho)}{e}$$

The horizontal component g of the product x forms the resistance to rolling, and it should be less than he, h being the coefficient of resistance to slipping, in order to admit of the cylinder a rolling on the horizontal plane bb^1.

As it is assumed in the last equation that the movement of the cylinder a takes place in the same direction as the action of the force g, this gives us—

$$y \geqq z$$

Or, in other words, if the horizontal force d be applied above the axis z of the cylinder a, slip might occur between the latter and the plane surface bb^1. This slip will take place if the force d

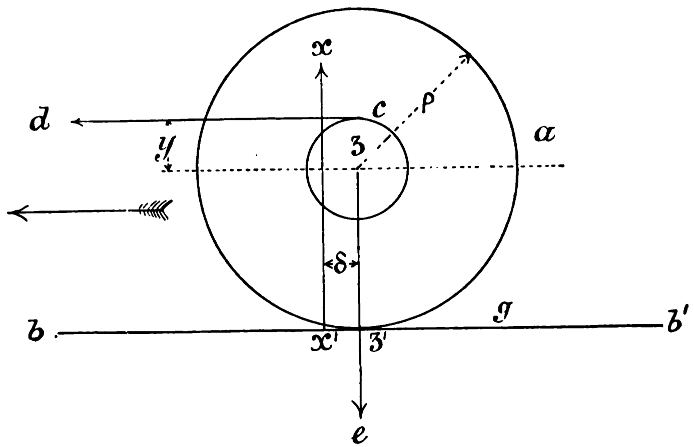

Fig. 2.—Diagram showing rolling resistance on plane surface, power applied horizontally.

that is applied be greater than the friction between the cylinder and the plane surface bb^1; that is to say, when the condition of things may be expressed by—

$$d > he$$

h, as has been already mentioned, being the coefficient of this friction. If, on the other hand, however, we have conversely—

$$d < he$$

then the cylinder a would roll in the contrary direction to that exerted by the force d, and in this case the formula—

$$\delta = \frac{d(y+\rho)}{z} = \frac{d(y+\rho)}{e}$$

would be applicable provided the distance y be regarded as a positive one, and that even if that distance be then reckoned as being above the point z, and counting the distance δ to the right instead of to the left of the point z^1. The location of the centre

of reaction of the fulcrum at the point x^1 is evidently due to the two bodies in mutually compressing each other coming in contact with each other no longer through a generator of the cylinder, but through that of a band of which the point x^1 is an interior point.

The resistance offered to rolling is explained thus by the fact that when a body is rolling or is on the point of rolling upon another body, the normal sources of resistances offered by the last-named have a product which is slightly in excess of the normal, at the geometrical point of contact, at that side towards which the rolling motion is taking place, or towards which the rolling motion is on the point of taking place.

Regarding experiments with the view of a practical determination of the resistance to rolling, the principal amongst the earliest workers in this field were Edgeworth (1797), Coulomb (1799), Rumford (1811), and Dupuit (1837). None of these experimenters, however, were able to place a practical value upon the resistance offered to the rolling of wheeled vehicles upon road surfaces, and it was not until General Morin, in the year 1838, took up the experiments of Coulomb, and having proved the truth of the principle enunciated by this latter, that the resistance to rolling was in an inverse proportion to the radius, that the experiments in this direction were continued until practical data were arrived at.

Although General Morin acknowledged the truth of the above principle, he nevertheless did not forget that the proportionateness between resistance and pressure was not a fixed general mathematical law, and that it was only extant in certain cases. He, however, admitted that, on solid macadam or stone roads, in a good state of repair, and on pavement, the proportionateness between resistance and pressure might be taken as being sufficiently exact for all practical purposes, and for ordinary applications. The amount of resistance encountered on pavement under light loads being less than that with heavy loads, no doubt because the latter had the effect of displacing the paving stones to a certain extent with regard to one another.

General Morin determined the value of the coefficient a in the formula of Coulomb, which was as follows:—

$$R = a \frac{P}{r}$$

In which R = the resistance at the circumference of the roller;
P = the pressure upon the roller;
r = the radius of roller;
a = the coefficient depending upon the nature of the surfaces in contact.

The result of General Morin's researches are recorded in the following table:—

VALUE OF THE COEFFICIENT a OF COULOMB'S FORMULA.

$$R = a \frac{P}{r}$$

Nature of the ground.	Value of a.
Very dry, even road, with a little dust	0·010 to 0·011
Slightly wet road, or one covered with a heavy coating of dust	0·012 to 0·013
Wet road free from mud	0·014 to 0·015
Very solid road, wet, with a little mud, very dry, or dry, offering an appreciable disintegration with dust, and detritus of materials ...	0·016 to 0·018
Slightly worn road, covered with thick mud ...	0·020 to 0·027
Pavement of Fontainebleau grit stone in ordinary condition	0·009
Pavement covered with mud	0·010 to 0·011

General Morin estimated besides this that the value of a = 0·010 was the minimum one for application to traction on roads made with silicious gravel during the fine periods of the summer season.

In 1840 General Morin set himself to solve the problem of registering the resistances which are opposed to the traction of vehicles, at the same time preserving as far as possible a lasting record of the information obtained. This led him to invent a registering dynamometer, from which instrument all those subsequently designed have had their origin, and by the use of which he was enabled to determine the laws under which a wheeled vehicle could travel on different road surfaces.

General Morin's experiments occupied several years of constant work, and he recorded the results in a work entitled "Experiments on the Traction of Vehicles." The following particulars, which

are of great interest and value, in relation to the subject under consideration, are translated from selected extracts summarized from General Morin's book, and given in an excellent treatise, published in Paris, entitled "Voitures Automobiles," by C. Milandre and R. P. Bouquet, from which work has also been derived much of the information just given.

The considerations which may exert a regular and noticeable influence upon the power required for traction, and which con-

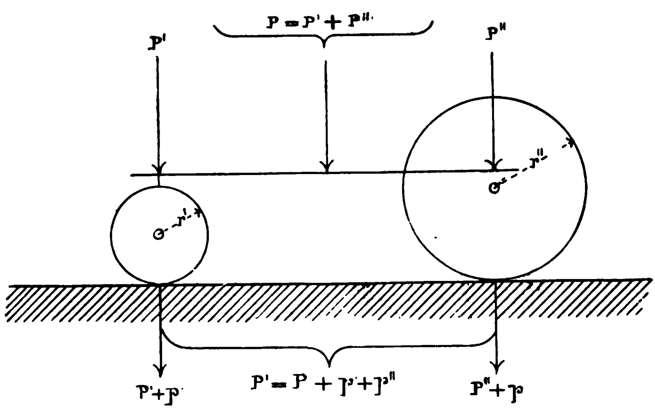

Fig. 3.—Diagram showing relation of the draught to the load for four-wheeled vehicles.

siderations it is desirable to investigate and substantiate, are the following:—

1. The load or pressure exerted upon the ground.
2. The diameter of the wheels.
3. The width of the tyres.
4. The rapidity of motion.
5. The obliquity of the tractive force.
6. The suspension, or the greater or lesser elasticity of the vehicle.

The following are the formulæ proposed by General Morin (see diagram, Fig. 3) for obtaining, with a sufficiently close approximation for practical purposes, the value of the resistance offered to the advance of four-wheeled vehicles on horizontal ground:—

$$R' = (A + f\rho)\left(\frac{P'}{r'} + \frac{P''}{r''}\right) + A\left(\frac{p'}{r'} + \frac{p''}{r''}\right) \text{ (vehicles with 4 wheels)}$$

R being the tractive force, parallel to the ground, which is necessary to overcome the resistance to rolling and the friction on the axles;

A the coefficient depending on the condition of the ground and the nature of the vehicle;

f the coefficient of friction of the axles in the boxes of the wheels;

ρ the diameter of the axles, which are supposed to be equal;

P is the weight of the vehicle without the wheels;

P′ and P″ are the proportion of P borne on the front and rear axles, that is to say, the load on the axles;

r' and r'' the radii of the wheels;

p' and p'' the weight respectively of the front and rear wheels.

The relation of the tractive effort developed to the total load moved forms the coefficient of traction, which is generally expressed in kilogrammes per ton or in thousandths.

It will be seen in the formula that in order to equalize the traction on the two sets of wheels the load should be so distributed that—

$$\frac{P' + p'}{r'} = \frac{P'' + p''}{r''}$$

and as without any appreciable error we can make—

$$p' = p''$$

we have as a general rule—

$$\frac{P'}{r'} = \frac{P''}{r''}$$

and as—

$$P = P' + P'',$$

the formula becomes—

$$R' = (A + f\rho)\frac{2P'}{r'} + A\left(\frac{p'}{r'} + \frac{p''}{r''}\right) = (A + f\rho)\frac{2P}{r + r''} + A\left(\frac{p'}{r} + \frac{p''}{r''}\right)$$

it being understood that we have—

$$\frac{P'}{r'} = \frac{P''}{r''} = \frac{P}{r' + r''}$$

The relation between the total resistance given and the total weight $P' = p' + p''$ is therefore—

$$\frac{R'}{P'} = \frac{A + f\rho}{r' + r''} \cdot \frac{2P}{P'} + A\frac{\left(\frac{p'}{r'} + \frac{p''}{r''}\right)}{P'}$$

In the case of a mechanically propelled vehicle, the weight of the wheels is only a small fraction of the total load, and it is therefore possible to neglect it, which then gives—

$$\frac{R'}{P'} = \frac{2(A + f\rho)}{r' + r''}$$

This latter formula shows that in the case of the supposed distribution of the load, the relation of the traction to the total load falls with A, f, and ρ, and is in an inverse ratio to the diameter of the wheels.

From the above the following interesting conclusions may be drawn:—

1. To increase as far as possible the diameter of the wheels.
2. To give to the axles a sufficient diameter only to meet the resistance, and with that object to form them of metal of the best quality.
3. To employ well-made and adjusted axle-boxes.

TABLE GIVING THE RELATION OF THE TRACTIVE FORCE TO THE TOTAL LOAD MOVED.

Description of road run on.	Values of l / ρ / r' / r'' / $f\rho$	Gun carriages. $0{\cdot}10^m$ to $0{\cdot}12^m$ / $0{\cdot}038^m$ / $0{\cdot}782^m$ / $0{\cdot}782^m$ / $0{\cdot}00247$	Wheeled vehicles. $0{\cdot}10^m$ to $0{\cdot}12^m$ / $0{\cdot}032^m$ / $0{\cdot}450^m$ / $0{\cdot}750^m$ / $0{\cdot}00208^m$	Stage coaches. $0{\cdot}10^m$ to $0{\cdot}12^m$ / $0{\cdot}032^m$ / $r'+r''=1{\cdot}15^m$ / $0{\cdot}00208$	Pleasure carriages. $0{\cdot}07^m$ to $0{\cdot}08^m$ / $0{\cdot}027^m$ / $0{\cdot}450^m$ / $0{\cdot}070^m$ / $0{\cdot}00175^m$
Stone roads—					
In excellent condition, very dry, very even		*p* 0·016 *t* 0·020	0·020	*pt* 0·023 *p* 0·021 *t* 0·024 *gt* 0·025	*pt* 0·025 *p* 0·020 *t* 0·024 *gt* 0·025
Slightly wet, or covered with dust, with some stones flush with the surface ...		0·022	0·028	*p* 0·030 *t* 0·037 *gt* 0·041	*p* 0·029 *t* 0·037 *gt* 0·041
Very hard, with large stones flush with the surface ...		0·018	0·023	*p* 0·025 *t* 0·038 *gt* 0·044	*p* 0·024 *t* 0·037 *gt* 0·044
Hard, slightly worn, and soft mud		0·029	0·037	*p* 0·038 *t* 0·046 *gt* 0·050	*p* 0·038 *t* 0·045 *gt* 0·049
Hard, with mud and ruts ...		0·035	0·045	*p* 0·048 *t* 0·054 *gt* 0·058	*p* 0·047 *t* 0·054 *gt* 0·058
With detritus and thick mud		0·041	0·053	*p* 0·056 *t* 0·063 *gt* 0·067	*p* 0·055 *t* 0·063 *gt* 0·067
Much worn, ruts of from 6 to 8 cm. and thick mud		0·054	0·070	*p* 0·073 *t* 0·081 *gt* 0·085	*p* 0·072 *t* 0·080 *gt* 0·084
Much worn, ruts of from 10 to 12 cm., thick mud, hard and uneven bottom ...		0·061	0·079	*p* 0·082 *t* 0·095	*p* 0·081 *t* 0·100
Grit stone pavement—					
Ordinary dry		0·013	0·017	*p* 0·017 *t* 0·026 *gt* 0·031	*p* 0·017 *t* 0·026 *gt* 0·030
Ordinary wet and muddy ...		0·017	0·022	*p* 0·023 *t* 0·030	*p* 0·022 *t* 0·030

NOTE.

l = width of tyre.
ρ = radius of axle bearing.
r' = radius of small wheels.
r'' = radius of large wheels.
= the coefficient of friction of axle.

$f\rho$ = moment of friction of axle.
p = travel at foot pace (1·50 m. about).
t = travel at trot (3·50 m. about).
gt = travel at fast trot (5 m. about).
pt = travel at foot pace and trot (2·50 m.).

TRACTION ON RISING GRADIENTS AND DISTRIBUTION OF LOAD ON WHEELS

The advantage offered by wheels of large diameter is merely that of diminishing the resistance caused by the inequalities of the surface passed over, and has no influence whatsoever upon that due to the action of gravity on a rising gradient. The resistance due to gravity when on an up gradient is the component of the load to be transported, parallel to the plane of the surface travelled upon, and the value is consequently entirely independent of the diameter of the wheels.

From this it will be obvious that if the load were to be raised to the highest maximum possible admitted by the diameter of the wheels on a level surface, the force required for propulsion might become excessive on a rising gradient, as it consists of the two following elements, viz. :—

First—A constant fraction of the total load entirely dependent on the gradient.

Second—The resistance offered by the surface that is being traversed, which is the only quantity that diminishes in proportion to the increase in the diameter of the wheels.

Attention should also be directed to the fact that in the case of vehicles having two trains of wheels of unequal diameter, the distribution of the load has an important influence on the tractive force required, because the amount of resistance due to the load upon the wheels of larger diameter is less than that upon the wheels of smaller diameter. It is obviously, therefore, an advantage to place a heavier load upon the first mentioned.

Theoretically, it may be taken, as a general rule, that if the load be equally distributed between the two axles, the distance between these latter has no effect. In practice, however, it is found that the closer the axles are placed together the easier the vehicle will roll; but, on the other hand, that the stability will be less.

WIDTH OF TYRES

General Morin's experiments with respect to the influence exerted by the width of tyres on the tractive force required, are embodied in the following three tables :—

TABLE I.

Width of tyres in mms.	Values of A.	
	Sandy.	Soft earth.
45	0·095	0·0604
90	0·0788	—
135	0·0739	0·0488
185	0·0632	—
225	0·0362	—
280	—	0·0411

TABLE II.

Nature of road surface.	Values of A.	Width of tyres.
Very solid stone road with large stones flush with surface (dry)	0·0107 0·0094	0·175m 0·060m
The same road (wet)	0·0155 0·0151	0·175m 0·060m
Earth road, covered with dust ...	0·0229 0·0212 0·0261	0·175m 0·115m 0·060m
Paved road	0·0106 to 0·0111	0·175m
"	0·0095 to 0·0092	0·115m
"	0·0094	

TABLE III.

Nature of road surface.	Total load in kilos.	Values of A.	Width of tyres.
Dry road with detritus of materials	6992 6140 4580 4590	0·0164 0·0163 0·0159 0·0140	0·175m 0·175m 0·175m 0·115m

A critical examination of the above tables shows that on roads in a good state of repair, and even on those in a comparatively bad condition, as well as on pavements when the bottom is solid, the resistance follows the axiom that friction is independent

of the area of the surfaces in contact, and the amount of resistance is practically independent of the width of the tyres, and consequently any increase in their width would only add unnecessarily to the weight of the vehicle. On the other hand, however, in the case of soft roads or on recently remetalled roads, and on roads constructed of friable materials, it is advantageous to increase the width of the tyres in proportion to the softness and penetrability of the road surface. From the point of view of the degradation of road surfaces, the best width of tyres for soft and compressible roads is one of 0·150 m., whilst in the case of ordinary roads and paved streets there is no advantage in exceeding 0·100 m. to 0·120 m.

SPEED AND SUSPENSION

Vehicles without Springs.—In the case of soft and giving surfaces the resistance to rolling was, according to the experiments in question, found to be independent of speed, which fact is due to there being only compression of the surface without shocks, and without communication of speed to the medium compressed. This is no longer the case when the vehicle is rolling on a hard and uneven surface, as in this case, by reason of the repeated shocks to which the wheels are subjected in surmounting the inequalities, there will be a constant tendency to reduce the speed of motion, which must be made up by motive power.

Vehicles hung on Springs.—On earth roads and soft surfaces the resistance is independent of the speed, even when slight ruts exist. But on a stone road in good condition, and on pavement, the influence exerted by speed increases in proportion as the road surface becomes harder.

At slow speeds and on hard road surfaces the effect of spring suspension is very slight, and, in fact, on stone roads in good condition, and on pavements, about the same value is found for A, both in the case of the most rigid description of vehicles, such as gun-carriages, for instance, and for those most carefully mounted on springs, such as diligences.

The law regulating the variation of the resistance in relation to speed is an expression of the equation—

$$A = \gamma - \delta (V - V')$$

γ being a constant representing in kilogrammes the value of A relatively to V′; δ being a constant coefficient numeral for each road corresponding to a given condition, and to a particular vehicle.

Taking as a term of comparison the speed of 1 metre per second, then the above equation will become—

$$A = \gamma + \delta (V - 1)$$

The following are the values obtained by General Morin for the constant δ—

Nature of road surface.	Description of vehicle.	Values of δ.
Smooth roads ...	Diligence	0·0022
	Vehicle (carriage) with springs	0·0008
Metz paving ...	Siege-gun carriage	0·0050
	Diligence	0·0022
Paris paving ...	Vehicle without springs ...	0·0089
	Same with six springs ...	0·0025
	Waggon body jointed to frame hung on springs	0·0020 to 0·0022

From the above it will be seen that on smooth roads the term $\delta(V - 1)$ decreases in proportion to the greater perfection with which the vehicle is hung on springs.

The following table gives the values of A corresponding to speeds between 3·6 kiloms. and 12·6 kiloms. per hour for the principal types of vehicles:—

TABLE GIVING VALUES OF "A" (*Morin*).

Speed in kilometres per hour ...		3·6	5·4	7·2	9·0	10·8	12·6
Description of vehicle.	Nature of road surface.	Values of A.					
Diligences	Road in good condition	—	—	—	—	—	—
	Dry	0·0120	0·0125	0·0130	0·0135	0·0140	0·0145
	Wet	0·0141	0·0151	0·0162	0·0173	0·0184	0·0200
Caleche	—	0·0120	0·0139	0·0158	0·0177	0·0196	0·0215
	Dry	0·0140	0·0151	0·0162	0·0173	0·0184	0·0200
Carriages jointed and hung on springs ...	Very dry ...	0·0100	0·0104	0·0108	0·0112	0·0116	0·0120
Carriages hung on springs	Grit stone pavement	0·0080	0·0093	0·0105	0·0115	0·0130	0·0142
Diligences	Ditto ...	0·0070	0·0083	0·0094	0·0105	0·0116	0·0127

From the above it will be seen that the resistance offered by stone roads in good repair, and by good pavement, was found to be almost the same in the case of carriages hung on springs when moving at the higher velocity. It is further to be observed that the resistance is always practically the same in the case of pavement, whilst it increases in winter on a stone road, and consequently that, when not greasy, a good hard pavement, well laid and close jointed, frequently affords a better surface for rolling than does a stone road in good repair. Moreover, the effects of shocks diminishing in proportion to the perfection with which the carriage is hung, it is obvious that the greater the speed at which the vehicle is intended to travel, the greater should be the care taken to secure the proper suspension of the vehicle.

The formula previously determinated—

$$R_1 = \frac{2(A + f\rho)}{r' + r''} \times P_1$$

will allow, by substituting the values for the letters, the solution, according to the case under consideration, of the amount of resistance to rolling for a vehicle of any description.

The former tables give the values of A, which should be applied in accordance with the conditions of traction, and the latter table gives the values of the coefficients of traction corresponding to the different types of vehicles at different speeds.

As regards the coefficient f (friction in axle boxes), its value will vary in accordance with the nature of the axles, and the method of lubrication employed, between 0·030 and 0·054. In practical working with good lubrication it may be taken as 0·040.

GENERAL RESULT OF EARLY EXPERIMENTS IN RESISTANCE TO TRACTION

The experiments of General Morin, although they did not enable any mathematical law upon the resistance to rolling to be arrived at, are, nevertheless, of great practical utility by reason of the numerous results attained, and the careful manner in which they were conducted. The general results obtained may be briefly summarized as follows :—

(*a*) Resistance to traction is in direct proportion to the load,

and in an inverse proportion to the diameter of the wheels of the vehicle.

(*b*) On a pavement or a good stone road the resistance to traction is independent of the width of the tyres when the latter exceed 7·5 to 10 cms., or say 3 to 4 ins

(*c*) At slow speeds, and other circumstances being equal, the resistance to traction is the same for vehicles with and without springs.

(*d*) On hard stone roads and on pavement the resistance to traction increases proportionately with the velocity at speeds in excess of 2·25 miles per hour. The increments to traction being less in proportion to the smoothness of the road and the perfection with which the carriage is hung.

(*e*) On earth roads, or roads freshly and thickly gravelled, resistance to traction is independent of velocity.

(*f*) On good pavement the resistance to traction at slow speeds is only about 0·75 of the resistance met with on stone roads. At higher speeds the resistance is equal.

(*g*) The smaller the diameter of the wheels the greater will be the destruction of the road surfaces, and vehicles without springs are also more destructive to road surfaces than those hung on springs.

SIR JOHN MACNEIL'S EXPERIMENTS

The experiments carried out by Sir John Macneil were made with an instrument devised by him for measuring the tractive force required on various road surfaces, to draw a waggon weighing 21 cwts. at a very slow speed, the results obtained being as follows :—

Description of road.	Total tractive force required, in lbs.	Tractive force per ton, in lbs.
Well-laid pavement	33	31·4
Stone road, made with six inches of broken stone of great hardness, laid on foundation of large stone pavement, or upon concrete	46	44
Old flint road, or road made with thick coating of broken stone laid on earth	65	62
Road made with thick layer of gravel laid on earth	147	140

From a large number of experiments Sir John Macneil deduced the following arbitrary formulæ for the calculation of the resistance to traction on the level, for roads of various kinds, and at different speeds :—

Let R = force required to move the vehicle, in lbs.;
W = weight of vehicle, in lbs.;
w = weight of load, in lbs.;
v = velocity, in feet, per second;
c = a constant number depending on the nature of the road surface.

The values of c for different kinds of road surface are as follows :—

Timber	$c = 2$
Paved road	$c = 2$
Well-made broken stone road, in a dry, clean state	$c = 5$
Well-made broken stone road, covered with dust	$c = 8$
Well-made broken stone road, wet and muddy...	$c = 10$
Gravel or flint road, dry and clean state ...	$c = 13$
Gravel or flint road, wet and muddy state ...	$c = 32$

$$\text{Stage waggon, } R = \frac{W + w}{93} + \frac{w}{40} + cv$$
$$\text{Stage coach, } R = \frac{W + w}{100} + \frac{w}{40} + cv$$

Divide the gross weight of the vehicle, in lbs., loaded, by 93 for a waggon, or by 100 for a coach, and to the quotient add $\frac{1}{40}$ of the weight of the load only. To the sum thus obtained add the product of the velocity in feet per second, multiplied by the constant for that particular kind of road. The sum will be the force in lbs. required to draw the carriage at a given velocity upon that description of road.

According to the results of the experiments of Leahy, the use of springs does not lessen the draught when the motion is so slow as to allow the body of the vehicle to be elevated and depressed just as much as the axle. The variation of the draught on hard irregular surfaces is as the square of the velocity. The following table of uniform draught is given :—

Surface.	Inclination.
Broken stone surface (ordinary)	Level
Close firm stone paving	1 in 48·5
Close timber paving	1 in 41·5
Close timber track	1 in 31·67
Close cut stone track	1 in 31·67
Iron tramway	1 in 29·25
Iron railway	1 in 28·5

The following deductions are given by Charié-Marsaines, as the result of experiments with respect to the durability, cost of maintenance, and maximum load that can be supported on paved surfaces, as compared with macadam roads. The wear on harness is less on pavement. The wear and tear of vehicles is greater. A horse lasts a shorter time on macadam. Harness lasts six years on pavement and five years on macadam. A vehicle lasts seven years on pavement and nine years on macadam.

The results obtained by Schwilgué are given in table below :—

Season of year.	Description of roads.	Load per horse.	Distance run per hour.	Work per hour in kilogrammetres.	Ratio.
Winter ...	Paved	1·306	3·300	4,309,800	1·644
Winter ...	Macadam	0·851	3·080	2,621,080	1·641
Summer ...	Paved	1·395	3·500	4,882,500	1·229
Summer ...	Macadam	1·141	3·480	3,970,680	1·229

RESISTANCE DUE TO RISING GRADIENTS

The additional resistance offered by an up gradient is dealt with by Macneil as follows: Let *ab* in the diagram, Fig. 4, represent a portion of an inclined road, *c* a vehicle just retained in its position by a force *d*, acting in the direction shown by the arrow. The vehicle *c* is retained in position by three forces, that is to say, by its own weight, *w*, acting in the vertical direction *ew*, by the force *w* applied in the direction *df* parallel to the road *ab*, and by the pressure *g* which is exerted by the vehicle *c* against the surface of the road, acting in the direction *eg* perpendicular to the surface. In order to determine the relative magnitude of the above three forces, draw the horizontal line

ah, and the vertical line *hb*. Now, as the two lines *ew* and *bh* are parallel to one another, and as they both cut the line *ab*, it follows that the two angles *ewb* and *abh* are equal, and as the two angles *egw* and *ahb* are right angles, the two remaining angles *weg* and *bah* must be equal ones, and the two triangles *ewg* and *abh* are similar ones.

It has been shown that the three sides of the triangle *ewg*

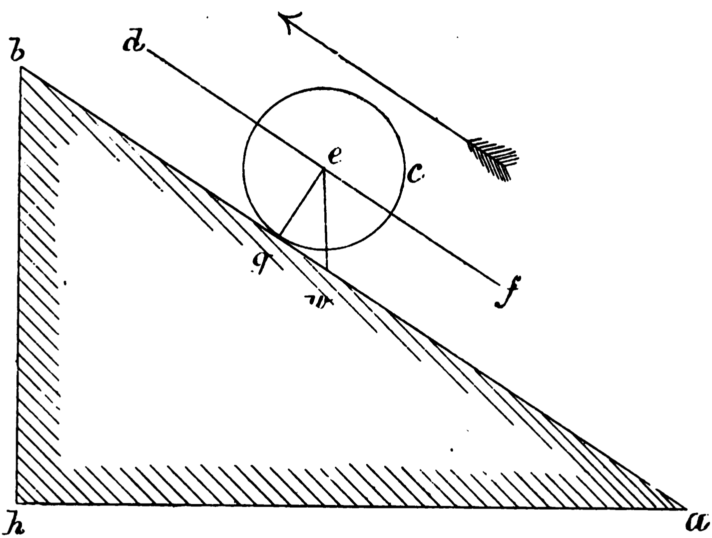

Fig. 4.—Diagram showing action of gravity on an inclined road surface.

are proportional to the forces by which the vehicle *c* is sustained, therefore so also are the three sides of the triangle *abh*. That is to say, the length of the road *ab* is proportional to *w*, the weight of the vehicle *c*; *bg*, the vertical rise, is proportional to *f*, the force required to sustain the vehicle upon the incline; and *ah*, the horizontal distance for the rise, is proportional to *g*, the force with which the vehicle presses upon the surface of the road.

Therefore—

$$w : ab :: f : hb$$
$$\text{and } w : ab :: g : ah$$

Thus, if *ah* be made of such a length that the vertical rise *bh* of the road is exactly 1 foot, then—

$$f = \frac{w}{ab} = \frac{w}{\sqrt{ah^2 + 1}} = w \cdot \sin \beta$$

and

$$g = \frac{wah}{ab} = \frac{wah}{\sqrt{ah^2 + 1}} = w \cdot \cos \beta$$

β being the angle *bah*.

The above formulæ can be reduced to the following verbal rules:—

To find the force requisite to sustain a vehicle upon an inclined road (the effects of friction being neglected), divide the weight of the vehicle in lbs., including its load, by the inclined length of the road, the vertical rise of which is one foot, and the quotient is the force required.

To find the pressure of a vehicle against the surface of an inclined road, multiply the weight of the loaded vehicle in lbs. by the horizontal length of the road, and divide the product by the inclined length of the same; the quotient is the pressure required.

To ascertain the resistance in passing up and down a hill, the resistance on a level road should first be calculated according to the rule before given (see Sir John Macneil's experiments). To this is to be added the force necessary to sustain the vehicle on the incline, in ascending, or in descending to subtract the same force from the resistance on the level.

The following table, calculated from these rules, and showing the force required to draw vehicles over inclined roads, ranging by 25ths from 1 in 600 to 1 in 7, has been abstracted from a treatise entitled "The Construction of Roads and Streets" (sixth edition), by Messrs. H. Law, M.I.C.E., D. K. Clark, M.I.C.E., and A. J. Wallis-Tayler, A.M.I.C.E.,* and will be found useful for reference and comparison:—

* London: Crosby Lockwood and Son. (Publishers of this work.)

Rates of inclination.	Angle with the horizon.	For a stage waggon of 6 tons gross.				For a stage coach of 3 tons gross.			
		Force required to draw the waggon up the incline.	Force required to draw the waggon down the incline.	Equivalent length of level road for an ascending waggon.	Equivalent length of level road for a descending waggon.	Force required to draw the waggon up the incline.	Force required to draw the waggon down the incline.	Equivalent length of level road for an ascending waggon.	Equivalent length of level road for a descending waggon.
	° ′ ″	lbs.	lbs.	miles.	miles.	lbs.	lbs.	miles.	miles.
1 in 600	0 5 44	286	241	1·085	0·9150	375	350	1·030	0·9690
,, 575	0 5 59	287	240	1·088	0·9116	373	350	1·032	0·9676
,, 550	0 6 15	288	239	1·093	0·9074	374	349	1·033	0·9662
,, 525	0 6 33	289	238	1·097	0·9029	374	349	1·035	0·9646
,, 500	0 6 53	291	237	1·102	0·8979	375	348	1·037	0·9629
,, 475	0 7 14	292	235	1·107	0·8926	376	347	1·039	0·9605
,, 450	0 7 38	294	334	1·113	0·8869	377	347	1·041	0·9588
,, 425	0 8 5	295	232	1·120	0·8801	377	346	1·043	0·9563
,, 400	0 8 36	297	230	1·128	0·8725	378	345	1·046	0·9535
,, 375	0 9 10	300	228	1·136	0·8642	380	344	1·049	0·9505
,, 350	0 9 49	302	225	1·146	0·8543	381	342	1·053	0·9469
,, 325	0 10 35	305	222	1·157	0·8433	382	341	1·056	0·9430
,, 300	0 11 28	309	219	1·170	0·8301	384	339	1·061	0·9381
,, 290	0 11 51	310	217	1·176	0·8245	385	338	1·064	0·9358
,, 280	0 12 17	312	216	1·182	0·8179	386	338	1·066	0·9336
,, 270	0 12 44	314	214	1·189	0·8111	386	337	1·068	0·9314
,, 260	0 13 13	315	212	1·196	0·8039	387	336	1·071	0·9286
,, 250	0 13 45	317	210	1·204	0·7963	388	335	1·074	0·9259
,, 240	0 14 19	320	208	1·212	0·7876	390	334	1·077	0·9226
,, 230	0 14 57	322	205	1·222	0·7785	391	332	1·080	0·9192
,, 220	0 15 37	325	203	1·232	0·7683	392	331	1·084	0·9156
,, 210	0 16 22	328	200	1·243	0·7573	394	330	1·088	0·9115
,, 200	0 17 11	331	197	1·255	0·7451	395	328	1·092	0·9071
,, 190	0 18 6	334	193	1·268	0·7319	397	326	1·097	0·9024
,, 180	0 19 6	338	189	1·283	0·7171	399	324	1·103	0·8968
,, 170	0 20 13	343	185	1·300	0·7004	401	322	1·109	0·8908
,, 160	0 21 29	348	180	1·319	0·6814	404	320	1·116	0·8839
,, 150	0 22 55	353	174	1·341	0·6587	406	317	1·123	0·8761
,, 140	0 24 33	360	168	1·364	0·6359	410	314	1·132	0·8673
,, 130	0 26 27	367	160	1·392	0·6079	413	310	1·142	0·8573
,, 120	0 28 39	376	152	1·425	0·5752	418	306	1·154	0·8451
,, 110	0 31 15	386	129	1·451	0·5491	423	300	1·169	0·8308
,, 100	0 34 23	398	122	1·510	0·4903	429	294	1·185	0·8142
,, 95	0 86 11	405	114	1·537	0·4634	432	291	1·195	0·8045
,, 90	0 38 12	413	106	1·566	0·4338	436	287	1·206	0·7937
,, 85	0 40 27	422	96	1·600	0·4004	441	282	1·219	0·7801
,, 80	0 42 58	432	85	1·637	0·3629	446	278	1·232	0·7677
,, 75	0 45 51	443	72	1·680	0·3204	451	272	1·247	0·7522
,, 70	0 49 7	456	57	1·728	0·2719	457	266	1·265	0·7345
,, 65	0 52 54	470	40	1·784	0·2161	464	258	1·285	0·7143
,, 60	0 57 18	488	19	1·850	0·1505	475	250	1·309	0·6903

Rates of inclination.	Angle with the horizon.			For a stage waggon of 6 tons gross.				For a stage coach of 3 tons gross.			
				Force required to draw the waggon up the incline.	Force required to draw the waggon down the incline.	Equivalent length of level road for an ascending waggon.	Equivalent length of level road for a descending waggon.	Force required to draw the waggon up the incline.	Force required to draw the waggon down the incline.	Equivalent length of level road for an ascending waggon.	Equivalent length of level road for a descending waggon.
	°	′	″	lbs.	lbs.	miles.	miles.	lbs.	lbs.	miles	miles.
1 in 55	1	2	30	508	—	1·926	0·0736	484	239	1·337	0·6620
,, 50	1	8	6	533	—	2·019	—	496	227	1·371	0·6283
,, 45	1	16	24	562	—	2·133	—	511	212	1·412	0·5871
,, 40	1	25	57	600	—	2·274	—	530	194	1·464	0·5354
,, 35	1	38	14	648	—	2·456	—	554	170	1·530	0·4690
,, 34	1	41	8	659	—	2·499	—	559	164	1·546	0·4535
,, 33	1	44	12	671	—	2·544	—	565	158	1·562	0·4370
,, 32	1	47	27	684	—	2·593	—	572	152	1·580	0·4193
,, 31	1	50	55	697	—	2·644	—	578	145	1·599	0·4007
,, 30	1	54	37	712	—	2·699	—	586	138	1·619	0·3805
,, 29	1	58	34	727	—	2·758	—	593	130	1·640	0·3592
,, 28	2	2	5	744	—	2·820	—	602	122	1·663	0·3363
,, 27	2	7	2	762	—	2·828	—	610	113	1·688	0·3119
,, 26	2	12	2	781	—	2·960	—	620	103	1·714	0·2854
,, 25	2	17	26	801	—	3·038	—	630	93	1·743	0·2566
,, 24	2	23	10	823	—	3·120	—	641	82	1·774	0·2257
,, 23	2	29	22	847	—	3·213	—	653	69	1·808	0·1919
,, 22	2	36	10	874	—	3·313	—	666	56	1·844	0·1554
,, 21	2	43	35	903	—	3·423	—	681	42	1·884	0·1150
,, 20	2	51	21	933	—	3·538	—	696	26	1·926	0·0780
,, 19	3	0	46	970	—	3·677	—	714	8	1·977	0·0221
,, 18	3	10	47	1009	—	3·826	—	734	—	2·032	—
,, 17	3	21	59	1053	—	3·991	—	756	—	2·092	—
,, 16	3	34	35	1102	—	4·178	—	780	—	2·160	—
,, 15	3	48	51	1157	—	4·388	—	807	—	2·234	—
,, 14	4	5	14	1221	—	4·629	—	839	—	2·322	—
,, 13	4	23	56	1294	—	4·906	—	875	—	2·423	—
,, 12	4	45	49	1379	—	5·229	—	918	—	2·540	—
,, 11	5	11	40	1480	—	5·611	—	968	—	2·679	—
,, 10	5	42	58	1600	—	6·067	—	1028	—	2·846	—
,, 9	6	20	25	1747	—	6·623	—	1101	—	3·048	—
,, 8	7	7	30	1929	—	7·315	—	1192	—	3·300	—
,, 7	8	7	48	2162	—	8·199	—	1308	—	3·621	—

In the French work entitled "Voitures Automobiles," which has been already referred to, the resistance offered by up-gradients is dealt with as follows: Inclines are defined by the elevation in millimetres corresponding to one metre traversed. A vehicle on an incline is a mover which is displaced on an

inclined plane, and if a be taken to represent the angle formed by this plane with the horizon (see diagram, Fig. 5), the power which will retain the body in motion, and which is the component

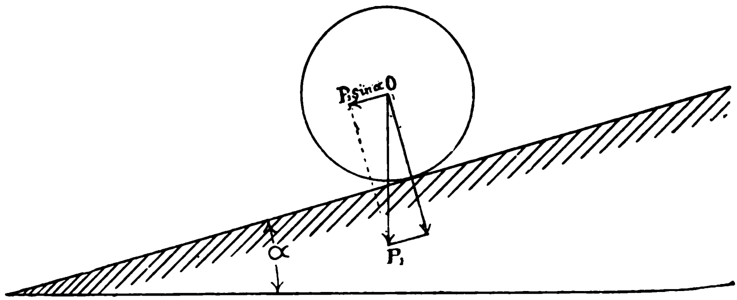

Fig. 5.—Diagram showing resistance due to a rising gradient.

of the total load P_1 parallel to the inclined plane P, is of the following value :—

$$R_3 = P_1 \sin a$$

a more simple expression of which is to say that it equals as many kilogrammes per ton as the incline measures millimetres per metre. As has been already mentioned, the force will be positive or negative in accordance with the direction in which the vehicle is moving, viz. up or down the incline.

Traction on an incline has also the effect of altering the value of the pressure on the axle bearings, which pressure, if it were represented by P, would become equal to P cos a; in practical working, however, this variation, which is but a small one, can be neglected.

RECENT EXPERIMENTS ON TRACTION ON COMMON ROADS

The results obtained by General Morin have been confirmed, and his experiments completed, by recent investigators, the advent of mechanically propelled vehicles having again drawn considerable attention to the subject. The most important of these recent experiments have undoubtedly been those of a French gentleman,

Mr. André Michelin, the manufacturer of the well-known tyres that bear his name, and whose primary object was to ascertain, for purposes of comparison, the results given from a tractional point of view, by the use of various different forms of tyres, viz. iron tyres, solid indiarubber tyres, and pneumatic tyres.

Before dealing with these comparatively recent experiments, it will be interesting to remark that Mr. Debauve, Ingenieur en Chef des Ponts et Chaussées, found, as the result of his experiments carried out in 1873, that resistance to traction varied on macadam roads from 32 kilogrammes per ton for heavy vehicles to 36 kilogrammes per ton for carriages; on paved roads he found these resistances to vary between 18 and 36 kilogrammes, for the same description of vehicles, according to the condition of the pavement.

The resistance to rolling in an omnibus travelling at a speed of 16 kilometres (9·94 miles) an hour he found to be as follows: 36 to 38 kilogrammes on macadam roads, and 29 to 31 kilogrammes on paved roads.

Clarke, as the result of his experiments, proposed to adopt the following empirical formula :—

$$R_1 = 30 + 4V + \sqrt{10V}$$

R being the resistance given in lbs. per ton, V the speed in miles per hour, and the road being supposed to be a good macadam.

Mr. André Michelin's experiments were carried out during the years 1896–7, and as they were conducted with great skill and care, the results obtained are of much importance.

The following details are extracted from an intelligent summary of these experiments given in the French work already mentioned (" Voitures Automobiles"), the question of comparison of the different tyres used being neglected for the present.

The first experiments of Mr. Michelin were carried out at Clermont-Ferrand with a well-hung brake, of which the following are the main particulars: Diameter of front wheels, 0·92 m.; diameter of rear wheels, 1·12 m.; weight of brake empty, without driver, 570 kilogrammes.

Subjoined is a brief summary of the results obtained, which are most pertinent to the present subject.

On a very even macadam road, with the brake empty, the following tractive force was required :—

	Walking pace.	Trotting.	Fast trotting.
	Kiloms.	Kiloms.	Kiloms.
Iron tyres	13·8	17·0	21·0
Pneumatic tyres	13·0	13·5	13·5

The speeds corresponding to the different paces of the horse were :—

	Walking pace.	Trotting.	Fast trotting.
	Metres.	Metres.	Metres.
Wheels with iron tyres ...	4·550	10·940	15·120
Wheels with pneumatic tyres	4·900	10·500	15·120

The coefficients of traction resulting from the above figures are tabulated below :—

Description of tyre.	At walking pace. 4550 to 4900 m.	At a trot. 10500 to 10940 m.	At a fast trot. 15120 m.
Iron tyres	0·0228	0·0239	0·0239
Pneumatic tyres	0·0242	0·0300	0·0368

The last experiments of Mr. Michelin date from 1897, and were carried out by means of a steam motor drawing a vehicle through a dynamometer mounted on another vehicle.

The coefficients of traction deduced from these experiments are summarized in the following table :—

TABLE GIVING COEFFICIENTS OF TRACTION (*Michelin*).

Nature of road surface.	Speed per hour.	Description of tyres.		
		Iron.	Solid india-rubber.	Pneu-matic.
	Metres.			
Good macadam, hard, dry, and dusty ...	11·700 (head wind)	0·0272	0·0245	0·0223
	11·700 (wind behind)	0·0253	0·0228	0·0208
	19·700 (head wind)	0·0344	0·0299	0·0248
	19·700 (wind behind)	0·0276	0·0252	0·0238
Good macadam, hard, slightly muddy ...	11·000 (wind behind)	0·0274	0·0265	0·0240
	20·000 (wind behind)	0·0399	0·0356	0·0318
Macadam, very wet	21·000 (wind behind)	0·0456	0·0426	0·0350
Old macadam, slightly broken up	22·000 (wind behind)	0·0338	0·0280	0·0225

A comparison of the results obtained by Mr. Michelin with those gained by General Morin so many years before is very interesting, and the close way in which the figures obtained by the two experimenters approximate adds very considerably to their practical value. For example: the results obtained by General Morin on a good macadam road in a dusty condition were, at a walk 100, at a trot 127, at a fast trot 152, whilst those obtained by Mr. Michelin were respectively 100, 123, and 160. On good pavement, dry, the first experimenter obtained, at a walk 100, at a trot 151, and the second 100 and 146. These figures are as near as can be expected considering the impossibility of obtaining roads in precisely the same condition. The figures obtained by Mr. Michelin are in almost every case slightly under those obtained by the formulæ of General Morin, a difference which is attributable to the superior manner in which the brake used by the former was hung upon springs, whilst the vehicle which was employed by General Morin was springless.

In 1897 a series of experiments were undertaken by Professor H. S. Hele-Shaw, F.R.S., M.I.C.E., for the Royal Lancashire Agricultural Society, the results obtained with respect to the tractive force for agricultural waggons being given briefly in the following table:—

	Wheels.		Tyres.		Weight of vehicle.	Load, in tons.	Tractive force per ton of load.	
	Fore.	Hind.	Fore.	Hind.			On turf.	On road.
	ins.	ins.	ins.	ins.	lbs.			
Agricultural waggons	39	42	4	4	2142	3	235	148
,, ,,	39	42	4	4	1895	3	277	125
,, ,,	37	41	4	4	1813	3	289	139
,, ,,	36	40	4	4	1752	3	227	170

A series of trials of self-propelled vehicles was carried out in 1897 before the Royal Agricultural Society, on which Professor W. C. Unwin, F.R.S., M.I.C.E., made an interesting report.

The experiments were made with the vehicles to determine the friction, by permitting them to run down an incline by gravity with the motors idle, and noting the speed acquired and the distance in which they came to rest. For the purposes of the

trial, distances were marked off on the descending gradient, the vehicles gently started at a distance of 300 ft., and in some cases 400 ft., from the first point, and from the speed attained between the second two of these fixed points, 200 ft. apart, a measure of the friction was obtained, another measure being obtained from the mean gradient from start to finish.

Mr. I. O. Baker, M.Am.Soc.C.E. (whose investigations were made in 1902), assumes resistance to traction of a vehicle upon a road to consist of the three independent elements, axle friction, rolling resistance, and grade resistance, and as the latter is understood to equal 20 lbs. per ton for 1 per cent. of grade, it is dismissed without further notice.

As regards axle friction, this is independent of the road surface, and the coefficient of friction varies with the material of the journal and its bearings, and with the lubricant. It is nearly independent of the velocity, and Mr. Baker's experiments show it to vary apparently inversely to the pressure. For the heavier classes of vehicles it is given as 0·0151 of the weight on the axle; with bad lubrication, however, these figures must be multiplied by from two to six. The tractive force required to overcome axle friction is given as from 3 to 3·5 lbs. per ton of the weight on the axle for ordinary waggons, and from 3·5 to 4·5 lbs. for waggons with medium-sized wheels and axles.

The resistance to rolling caused by the yielding of the road, and the wheels in consequence continually climbing an incline, is measured by the horizontal force necessary at the axle to lift it over the obstacle, or to roll it up the incline, and varies with the speed, the presence or absence of springs, and the nature of the surface.

The effect of the diameter of the wheels on rolling resistance is concluded to vary nearly inversely as the square root of the mean diameter.

Experiments were carried out with the following three sizes of wheels, viz.: 44 ins. front and 56 ins. hind, equal to 50 ins. mean diameter; 36 ins. front and 40 ins. hind, equal to 38 ins. mean diameter; and 24 ins. front and 28 ins. hind, equal to 26 ins. mean diameter; the load being in each case $1\frac{3}{4}$ ton, American, or 3500 lbs., and the tyres 6 ins. in width. From these experiments the table below has been deduced, showing the effect of the size of wheels on traction :—

EFFECT OF THE SIZE OF WHEELS ON TRACTION (*Baker*).

Road surface.	Tractive force in lbs. per ton. Mean diameter of front and rear wheels— 50 ins.	38 ins.	26 ins.
Macadam, slightly worn, clear, fair condition	57	61	70
Gravel road, dry, sand 1 in. deep, loose stones	84	90	110
Gravel road, up-grade of 2·2 per cent., ½ in. wet sand, frozen below	123	132	173
Earth road, dry and hard	69	75	79
,, ½ in. sticky mud, frozen below, rough	101	119	139
Timothy and blue grass sod, dry, grass cut	132	145	179
,, ,, ,, wet, spongy	173	203	281
Cornfield, flat culture, across rows, dry	178	201	265
Ploughed ground not harrowed, dry, cloddy	252	303	374

With respect to width of tyres, the traction is increased if the wheel cuts into the road, but where little or no indentation occurs the width of tyres has practically no effect on traction.

The effect of speed is that the rolling resistance increases with the velocity owing to the effect of the shocks or concussions produced by the irregularities of the road surface. From two to six or eight times as much force is required to start a vehicle as to keep it in motion at 2 or 3 miles an hour.

Springs decrease the traction by decreasing the concussions due to the irregularities of the ground, and are, therefore, more effective at high speeds than low, and on rough roads than on smooth.

The tractive force on different road surfaces was determined by a Baldwin dynagraph.

According to the New York *Automobile*, from tests made by the Government Office of Road Inquiry, the following table has been compiled, which shows the tractive force necessary to haul a load of one ton on roads of the best macadam on the gradients given. The table also gives the equivalent length of each mile of gradient in miles of level road :—

Rate of inclination.	Angle with the level.	Tractive force.	Equivalent length of level road in miles.
		lbs.	
—	° ′ ″	—	—
Level	0 00 00	38	1·00
1 in 500	0 6 53	42	1·10
1 in 100	0 34 23	58	1·52
1 in 80	0 42 58	63	1·66
1 in 60	0 57 18	71	1·87
1 in 50	1 08 16	78	2·05
1 in 40	1 25 57	88	2·30
1 in 30	1 54 37	104	2·73
1 in 25	2 17 26	118	3·10
1 in 20	2 51 21	138	3·63
1 in 15	3 48 51	171	4·50
1 in 10	5 42 58	238	6·26

It is also stated that the extra force necessary to start a carriage on a gradient does not increase in proportion, but, relative to the running force, decreases as the gradient increases.

RESISTANCE DUE TO THE AIR

Regarding the resistance offered by the air, this is a quantity very difficult to appreciate, inasmuch as it comprises several elements liable to considerable variation. On a calm day the amount of resistance is entirely dependent upon the speed of the vehicle, and in the case of those travelling at very slow speeds the resistance is so small that it can be as a rule entirely neglected in practice. The opposition due to wind pressure, which, according to its direction, increases more or less the above resistance, is practically impossible of estimation with any degree of accuracy. From the experiments made by Mr. Thibault it appears that the resistance of the air against the square base of a prism, the lateral sides of which are placed in the direction of motion, relatively to the unity of the horizontal path traversed by the prism, has the following value :—

$$R_2 = \theta \epsilon S V^2$$

R_2 is the work required to overcome the resistance that the air opposes to the movement of the prism.

θ = 0·0625 (constant).

ϵ is the coefficient depending on the proportion of the length l of the prism as compared to the side a of its base; and if—

$l = 3a$	$\epsilon = 1{\cdot}10$
$l = a$	$\epsilon = 1{\cdot}17$
$l < a$ (thin plate)	$\epsilon = 1{\cdot}43$

In the case of motor-propelled vehicles, according to the authors of "Voitures Automobiles," in the majority of cases it is safe to take—

$$\epsilon = 1{\cdot}10$$

S is the surface of the base of the prism in square metres,

V is the speed of displacement of the prism in metres per second.

Mr. Thibault's experiment demonstrated that in the case of two square surfaces placed directly behind each other and covering one another exactly, the resistance of the air against the second surface will be completely annulled so long as the space between the two surfaces is a small one, and that the resistance on the second surface will be $\frac{7}{10}$ of that on the first surface when the distance separating them is equal to the side of the surface.

RESISTANCE DUE TO STARTING

Theoretically, there should be no special resistance due to starting, and whatever resistance there may exist is caused by defective lubrication of the axles, or to irregularities of the road surface. The French authorities already mentioned state that it is prudent to count upon a resistance to starting on a stone road in bad condition, that will exceed in value from a fifth to an eighth that of the normal resistance to rolling. On a good stone road and on asphalt, however, the starting resistance should not exceed the normal rolling resistance. As the power required to start a mechanically propelled vehicle must be sufficient to overcome both the resistances opposed to its motion and also the inertia of the vehicle, it must necessarily increase with the speed of starting. Each mechanically propelled vehicle, therefore, will have a maximum speed of starting corresponding to the maximum power of its motor, and the normal speed of motion can only be

attained after a considerable distance has been traversed. Starting may, therefore, be considered as a loss of time, which will be longer or shorter in extent in accordance with the greater or lesser speed of starting.

The authority above quoted gives the following formula for the resistance of mechanically propelled vehicles—

$$R = R_1 + R_2 \pm R_3$$

R being the resistance developed during the traction of a self-propelled vehicle;

R_1, the resistance to rolling and that due to friction in the axle boxes;

R_2, the resistance due to the air;

R_3, the resistance due to gradients.

If the expressions R_1, R_2, and R_3 be replaced by their values previously determined, then we have the following equation:—

$$R = \frac{2(A + f\rho)P_1}{r' + r''} + \theta\epsilon SV^2 \pm P_1 \sin a$$

A = coefficient depending on the nature of the road surface and the nature of the vehicle, the value of which has been given in the preceding tables.

f = coefficient of friction of the axles in the boxes, varying from 0·03 to 0·054.

ρ = the diameter of axles, supposed equal;

P_1 = the total weight of the vehicle;

r' = the radius of the front wheels;

r'' = the radius of the rear wheels;

a = the angles of the inclines with the horizon;

θ = 0·0625 (constant);

ϵ = the coefficient depending on the proportion of the length of the vehicle as compared with its section;

S = the surface of the vehicle exposed to the wind;

V = the speed in metres per second.

The following formula for calculating the necessary power to apply to motor-driven vehicles according to the load, the gradient, and the speed, is given by Messrs. Boramé and Julien:—

$$F = P(0{\cdot}025 + 0{\cdot}0007v + \rho)Sv^2 \times 0{\cdot}0048,$$

in which F = the tangential effort on the driving-wheels;
P = the weight in kilogrammes of the entire load;
0·025 = coefficient of resistance to rolling on ordinary roads, and for wheels 0·80 m. in diameter;
v = speed in kilometres;
$0{\cdot}0007 \times v$ = the resistance due to the shocks caused by the irregularities in the road surface;
S = surface in square metres exposed to the resistance of the air;
$S v^2 \times 0{\cdot}0048$ = resistance of air.

ADHESIVE POWER OF MOTOR VEHICLES

The adhesive power of a mechanically propelled vehicle must exceed the tractive force of the motor on the road surface, otherwise the wheels will slip. This point, however, which is one of great importance in the case of railway locomotives, is of far less moment in that of mechanically propelled vehicles adapted to run on common roads, inasmuch as the coefficient of adhesion in the latter case is much higher. In fact, as a general rule, the adhesion of motor-propelled vehicles on common roads is in excess of the propelling power, and slip only occurs under exceptional circumstances, such as in the case of large vehicles provided with very powerful motors, when starting on greasy pavement or on asphalt.

A mechanically propelled vehicle has therefore a limit to its tractive power entirely independent of that of its motor, and dependent entirely upon the load upon its driving-wheels. The adherence of a mechanically propelled vehicle can be computed by the following formula:—

$$ka \begin{smallmatrix} = \\ < \end{smallmatrix} \frac{k'c}{d}$$

a being the tractive effort in pounds;
b, the resistance at the circumference of the driving-wheels;
c, the total weight of the vehicle;
k, the coefficient of loss due to the transmission of power from the motors to the driving-wheels;
k', the coefficient of friction between the wheels and the road surface;
d, the portion of load carried on driving-wheels.

Up to the present no experiments, with which the writer is acquainted, have been carried out with a view to ascertaining the adherence of power-propelled vehicles on common roads, under various conditions of road surface. Turning again, therefore, to the experiments made so many years ago by General Morin, we find the following results of experiments on the friction of various bodies given in his work entitled "Notions Fondamentales de Mécanique."

Substances.	Angle of repose.	Coefficient of friction.
	°	
Oak on oak, fibres parallel ...	31½	0·62
,, ,, ,, perpendicular ...	28½	0·54
Oak on elm, fibres parallel ...	20½	0·38
Elm on oak, ,, ,, ...	34½	0·69
Wood on wood, dry	14–26½	0·25–0·5
,, ,, soaped	2–11½	0·04
Metal on metal, dry	8½–11½	0·2—0·2
,, ,, wet and clean ...	16½	0·150·3
Metals on oak, dry	26½–31	0·5–0·6
,, ,, soapy	11½	0·2
Leather on metals, dry	29½	0·56
,, ,, wet	20	0·36
,, ,, greasy	13	0·23
,, ,, oily	8½	0·15
Smoothest and best greased surfaces	1¾–2	0·03–0·036

CHAPTER III

POWER REQUIRED FOR MOTOR VEHICLES

Calculating the Power required for Motor Vehicles—Testing the Engine and Gear—Testing the Vehicle—Graphic Calculations.

CALCULATING THE POWER REQUIRED FOR MOTOR VEHICLES

To calculate the power required for a motor vehicle is a task of great difficulty, and one to which, owing to the varying nature of the resistances to be overcome, the answer can only be in any case an approximate one. It is always, moreover, advisable to allow a very considerable additional margin of power, as that found by calculation will generally be too low for practical work.

In a paper read before the Society of German Engineers by Mr. Hugo Guldner, and published in the *Motorwagen* in 1900, the author gives a formula which is claimed to approximate as nearly as practicable to existing conditions, and which is introduced by the following observations, which have been abridged as far as possible consistent with giving the necessary explanations :—

1. Frictional resistance (Wr) of the wheels, resulting from the rolling friction of the tyres on the road and that between the hubs and the axles, the latter being a factor which may be neglected except in the case of heavy goods waggons. We have therefore—

$$\text{For light vehicles, } Wr = \frac{2Qf}{r + r_1} \text{ kilogs. . . . } \quad (1)$$

$$\text{For heavy vehicles, } Wr = \frac{2Q(f + d\mu)}{r + r_1} \text{ kilogs. . } \quad (2)$$

Q = total weight in kilogrammes;
r = radius of front wheels;
r_1 = radius of rear wheels;
d = mean diameter of axle in millimetres;
f = coefficient of friction on road;
μ = coefficient of friction on naves.

In the second equation the deduction of the latter is made from $Wra = \frac{11}{4} \times Qdr = 0{\cdot}785\ Qd\mu$, to which $Wra = Qd\mu$ is added to allow for the additional friction due to jolting.

Morin gives for f, at a speed of from 12 to 13 kiloms. per hour on ordinary good roads, a value between 0·016 and 0·02. μ under average conditions is less than 0·05, therefore μ is usually from 0·0025 to 0·003.

Taking for lighter vehicles a mean wheel radius of 400 mms., and for heavier vehicles one of 525, say 400 to 425 for the front and 625 to 650 for the rear wheels, which gives, taking f at 0·018 and $d\mu$ at 0·003, the following formulæ for (1) and (2):—

$$Wr = \frac{0{\cdot}018Q}{0{\cdot}4} = \frac{Q}{22} = 0{\cdot}045Q \text{ kilogs., about} \quad (1\text{A})$$

$$Wr = \frac{Q(0{\cdot}018 + 0{\cdot}003)}{0{\cdot}525} = \frac{Q}{25} = 0{\cdot}04Q \text{ kilogs.} \quad (2\text{A})$$

2. The resistance due to the air. Assuming that the front of the vehicle is a flat surface, F square metres in area, forced through the air in a direction at right angles to the surface at a speed of v metres per second, then the resistance of dry air at zero centigrade and 760 mms. pressure will be—

$$W_1 = 0{\cdot}12248Fv^2 \text{ kilogs.} \quad (3)$$

If the front of vehicle be rounded—

$$W_1 = 0{\cdot}085Fv^2 \text{ kilogs.} \quad (4)$$

In practice, however, the coefficient must be increased to 0·125, and taking the surface $F = bh$, b being the width of the wheel gauge, and h the maximum height of the vehicle above the front axle, we have then for the fourth equation—

$$W_1 = 0{\cdot}125bhv^2$$
$$\text{or } 0{\cdot}125Fv^2$$

and at a mean speed of 6·3 metres per second

$$W_1 = 6{\cdot}3 \times 6{\cdot}3 \times 0{\cdot}125F = 5F \text{ kilogs., about} \quad (4\text{A})$$

The value of v depending upon both the speed of the vehicle and any independent motion of the air, a head wind will make v greater than the speed of the vehicle, and a wind behind will make it less. The latter cannot be taken into consideration, but allowance must be made for the former, and for this purpose 10 metres, which is an average wind speed, should be added to the speed of the vehicle. This gives us—

$$W_1 = 0{\cdot}125(v + 10)2 \text{ kilogs.} \quad . \quad . \quad . \quad (4\text{B})$$

3. The resistance due to gravity. If this be called Ws, we have—

$$Ws = Q \sin a \text{ kilogs.} \quad . \quad . \quad . \quad . \quad . \quad (5)$$

a being the angle the road surface makes with the horizon. Taking, then, the usual practice for inclines, and denoting the quotient of the vertical height by the length of the road, in order to arrive at it by s, we have—

$$Ws = Qs \text{ kilogs.} \quad . \quad . \quad . \quad . \quad . \quad (5\text{A})$$
$$\text{for } s = \sin a.$$

As, however, speed is always reduced on a rising gradient, and a portion of the power normally employed for the maintenance of speed is used for overcoming gravity, the value of Ws can be, as a rule, neglected.

4. Friction due to the transmission of power from the motor to the driving axle. This factor will vary within a wide range in accordance with the type of gearing used. In practice not more than 60 per cent. of the actual power developed by the piston can be relied upon.

From the different formulæ, W being the power required and e the proportion transmitted to the driving wheels, we get the following :—

$$W = \left(\frac{2Q(f + du)}{r + r_1} + 0{\cdot}125Fv^2 + Qs\right) = e \text{ kilogs.} \quad . \quad (6)$$

or without the factor for rising gradient, the values of f, d, u, r, and v being taken as before, and $e = 0{\cdot}6$.

For light vehicles—

$$W = \frac{0{\cdot}045Q + 5F}{0{\cdot}6} \text{ kilogs.} \quad . \quad . \quad . \quad . \quad (7)$$

For heavy freight vehicles—

$$W = \frac{0{\cdot}04Q + 5F}{0{\cdot}6} \text{ kilogs.} \quad . \quad . \quad . \quad . \quad . \quad (8)$$

For the motor power required we have—

$$\frac{\frac{2Q(f + du)}{r + r_1} + 0{\cdot}125Fv^2 + Qs}{0{\cdot}6} + \frac{\sqrt{\quad}}{75} \text{ H.P.} \quad . \quad . \quad (9)$$

or Qs may be again left out, and as it has been demonstrated that F is, in the case of large vehicles, usually about 2 square metres, and that 10 kiloms. per hour can be taken as the average speed, we finally arrive at—

$$\text{H.P} = \frac{0{\cdot}04 \times 1000 + 5 \times 2}{0{\cdot}6} \times \frac{10000}{3600 \times 75} = 3 \text{ H.P., about} \quad (10)$$

The following formula is given by the French engineers, Messrs. Boramé and Julien :—

$$Ne = \frac{eP(0{\cdot}025 + 0{\cdot}0007v + pSv^2 + 0{\cdot}0048)}{75} \text{ H.P.} \quad . \quad (11)$$

e being the speed of the vehicle in metres per second;
v the speed of the vehicle in kilometres per hour;
P the gross weight of the vehicle in kilogrammes;
p the incline in vH;
S the area of the front of the vehicle in square metres;
0·025 the coefficient of rolling friction for pneumatic tyres 800 mms. in diameter.
$0{\cdot}0007v$ the loss of power through jolting;
$0{\cdot}0048sv^2$ the resistance of the air.

This formula gives too low a result, and is only suitable for use in the case of very light vehicles on good roads. At least 70 per cent. should be added to its estimate of power required.

The author observes on the impossibility of applying to motor vehicles propelled by internal combustion engines the science of thermodynamics. For example, the indicator diagram cannot be made use of. Numerous influences which cannot be reduced

to arithmetic exist, and besides the calorific value of the fuel we have the proportion of air in the explosion chamber, the amount of compression, the greater or lesser completeness of combustion, the resistance of the piping, all of which factors vary largely within unknown limits.

The mean pressure in kilogrammes per square centimetre, required to produce x h.p., the area of the piston being q square centimetres, and the speed c metres per second, will be $\frac{300x}{qc}$, which for an efficient coefficient of 0·6 becomes $\frac{500x}{qc}$. In stationary engines the coefficient reaches 0·8 to 0·85; in motor vehicles, however, the irregularity of motion, and consequently the friction, are considerably more. Tests of a motor vehicle when stationary are, by reason of the above facts, of no practical value.

The tables compiled from actual experiments with motor vehicles give the lowest value of $\frac{500x}{qc}$ at 3·16 kilogrammes, and the highest at 7·54. In trials conducted in 1894 the highest obtained was 5·1 with a motor exhausting at the pressure of 17 atmospheres.

For the class of vehicles under consideration—

$$\text{H.P.} = \left(\frac{300x}{qc} \times \frac{11d^2}{4} \times sn\right) \div (60 \times 75 \times 2)$$

n being the number of revolutions made per minute, and d and s being put in metres, gives—

$$\text{H.P.} = \frac{10000 \times \frac{300x}{qc} \times 11d^2sn}{60 . 75 . 2 . 4}$$

If the factors d, s, and n given for every motor be eliminated, the remaining fraction—

$$\frac{1000 \times \frac{300x}{qc} \times 11}{36000}$$

may be denoted by the symbol A, which then becomes a new

coefficient of the specific output of power, and admits of the following simple and easily remembered formula—

$$\text{H.P.} = \text{A}d^2sn$$

The value of A varying from 2·07 to 4·69, and some trustworthy averages being—

$$\frac{300x}{qc} = 3{\cdot}64$$

$$\frac{500x}{qc} = 4{\cdot}855$$

$$\text{A} = 3{\cdot}09$$

From which is deduced the following empirical formula:—

$$\text{H.P.} = \frac{3{\cdot}64qc}{75 \times 4} = \frac{qc}{85}$$

qc being square centimetres and *e* metres per second, or—

$$\text{H.P.} = 3d^2sn$$

d and *s* being in metres.

There are two points that have to be given careful consideration to throughout, that is to say, the diminution in the weight of the reciprocating parts, and the great increase that has taken place in the number of revolutions. For instance, the first has been reduced to from 40 to 50 grammes per square centimetre of piston area, and the second, owing to the extremely limited time that it allows for the cycle of operations taking place at each stroke, causes the action of the ignition apparatus at the proper time to become a very important factor in the power required.

In an article by Mr. Gustav Mees that appeared in a subsequent number of the *Motorwagen*, the author criticizes the formulæ developed by Mr. Guldner, which he states give results which are far too high as regards the power required, and are not in accordance with practical experience. Mr. Mees proceeds to prove this statement by a comparison with the results realized by Guldner's formulæ of the performance of a 24-horse-power Daimler racing car weighing 1400 kilogs., and capable of travelling at a speed of 96 kiloms. an hour on a good level road. Taking

the speed at 90 kiloms. an hour, and the total weight of vehicle with passengers at 1600 kilogs., Guldner's formulæ give for the frictional resistance $0{\cdot}04 \times 1600 = 64$ kilogs. Reckoning, therefore, an efficiency of 60 per cent., the power required for the above-mentioned speed would be—

$$\frac{64 \times 90000}{3600 \times 75 \times 0{\cdot}6} = 35{\cdot}5 \text{ H.P.}$$

Mr. Mees considers that Guldner has made a mistake (in spite of the authority of Morin) in introducing into the resistance formula the wheel diameters, which he thinks should be left out of consideration altogether. This authority is also of opinion that axle friction can be ignored for practical purposes. These observations and criticisms, however, refer more particularly to motor vehicles intended to travel at high speeds, and it does not therefore greatly concern us to investigate any further into them. In the opinion of the writer, Guldner's formulæ by no means give too high results, and will be found of service in making calculations respecting both the lighter and heavier classes of mechanically propelled vehicles adapted for business purposes.

The following data is given by Mr. Herschmann, in a paper read before the American Society of Mechanical Engineers, for a waggon capable of carrying a load of 3 tons and able to mount an incline of 1 in 10 at 2 miles per hour :—

Internal friction considered; this would call for power to lift about $\frac{1}{6}$ (equals an incline of 1 in 6) of the gross weight a height of 10,560 feet per hour.

Assuming the gross weight to be 6·5 tons, we have—

$$\frac{6{\cdot}5 \times 2240}{6} \times \frac{10560}{60} \text{ ft.-lbs. per minute} = 427046 \text{ ft.-lbs.}$$

In other words, to lift the waggon, irrespective of road resistance, we require 12·94 horse-power. To overcome road resistance (tractive effort assumed to be from 60 to 120 lbs. per ton) we require—

$$60 \times 6{\cdot}5\left(\frac{2 \times 5280}{60}\right)\left(\frac{1}{33000}\right)\left(\frac{1}{0{\cdot}60}\right) = 3{\cdot}47 \text{ H.P.}$$

$$\text{or } 120 \times 6{\cdot}5\left(\frac{2 \times 5280}{60}\right)\left(\frac{1}{33000}\right)\left(\frac{1}{0{\cdot}60}\right) = 6{\cdot}94 \text{ H.P.}$$

The waggon must, therefore, have machinery capable of producing, when going uphill, about a total of 20 horse-power.

TESTING THE ENGINE AND GEAR

The following method of testing the engine and gear of a motor waggon is given by the same authority: "The power of a motor waggon should be always measured in foot-pounds at the rim of the driving wheels; for this purpose the drivers may rest on a revolving roller. The latter is in one with a pulley (*r*) over which a strap is slung, fastened to a dynamometer (*d*) at one end, and carrying a weight (*w*) at the other end (see Fig. 6).

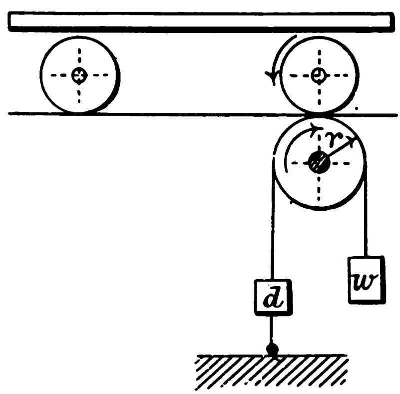

Fig. 6.—Diagram showing method of testing engine and gear.

The work done at the rim is in foot-pounds.
$2\pi(r) \times n \times (w - d)$.
r = radius of pulley.
d = reading of dynamometer in pounds.
The friction of engine and gearing can thus be found.

TESTING THE VEHICLE

For the purpose of ascertaining the frictional resistance to motion of the waggon itself, says the same authority, the latter is placed on a measured incline at A, and permitted to roll down

and along the level portion of the road BC (see Fig. 7). While passing the point D, between B and C, and at a distance of (d) from A, its speed measures to be (v). We have then: W (weight of waggon in pounds) × H = foot-pounds, due to

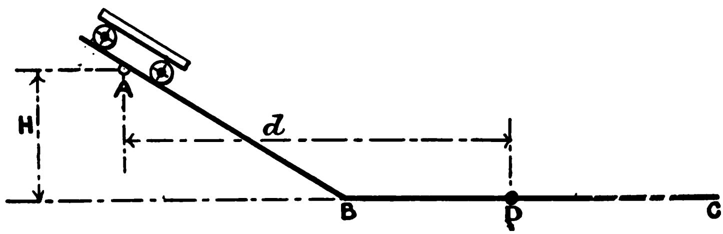

Fig. 7.—Diagram showing method of testing motor vehicle.

gravity work. FWd = friction work in foot-pounds = $WH - \frac{Wv^2}{2g}$ being work due to gravity less the kinetic energy of the waggon in passing the point D. The friction is then found to be in pounds per pound of $WF = \left(H - \frac{v^2}{2g}\right)\frac{0{\cdot}1}{D}$.

The following table gives the results obtained at different trials with some heavy freight steam vehicles:—

DEAD WEIGHTS AND CARRYING CAPACITIES OF STEAM WAGGONS FROM ACTUAL PERFORMANCES.

	Dead weight, in lbs.	Useful load carried, in lbs.	Per cent. of dead load.
Two-ton steam waggon ...	5400	4500	About 84
Three-ton ,, ...	6700	8200	,, 122
Four-ton ,, ...	6500	9200	,, 140

From the above it will be seen that the percentage of useful load carried by a heavy freight vehicle advances very considerably as the dead weight increases, thus proving most conclusively that the advantage is greatly on the side of the heavier classes of freight vehicles.

GRAPHIC CALCULATIONS

The following diagrams (Figs. 8 and 9), published by *The Horseless Age*, New York, are intended for the purpose of quickly solving many calculations necessary in motor-car design. The first diagram (Fig. 8) shows the relation of the speed of the vehicle in miles per hour, the diameter and revolutions per

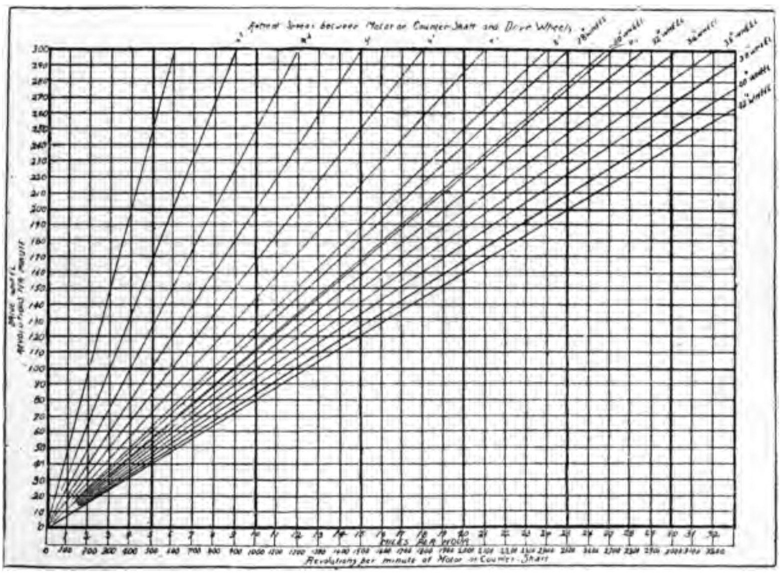

Fig. 8.—Diagram showing the relation of the speed of vehicle, diameter and revolutions of drive wheels, and ratio of speeds of countershaft to drive wheels.

minute of the drive wheels, and the ratio of speeds of the countershafts or motor shaft to the drive wheels; the second (Fig. 9) shows the relation of the speed of the vehicle to the traction, the percentage of gradient, and horse-power required under various conditions. No allowance is made in the diagram for air resistance, and, if necessary, additional power will be required to overcome this force.

The following examples are given, illustrating the use of the diagrams or charts:—

Assuming a vehicle, whose drive wheels are 32 ins. diameter, going at a speed of 15 miles per hour, the motor making four revolutions to one of the drive wheels.

From Fig. 8 it will be found that the intersection of the vertical line representing 15 miles per hour, and the diagonal line representing a wheel 32 ins. in diameter, corresponds to 157·5, the revolutions per minute of the drive wheel.

To find the speed of the motor, find the intersection of this

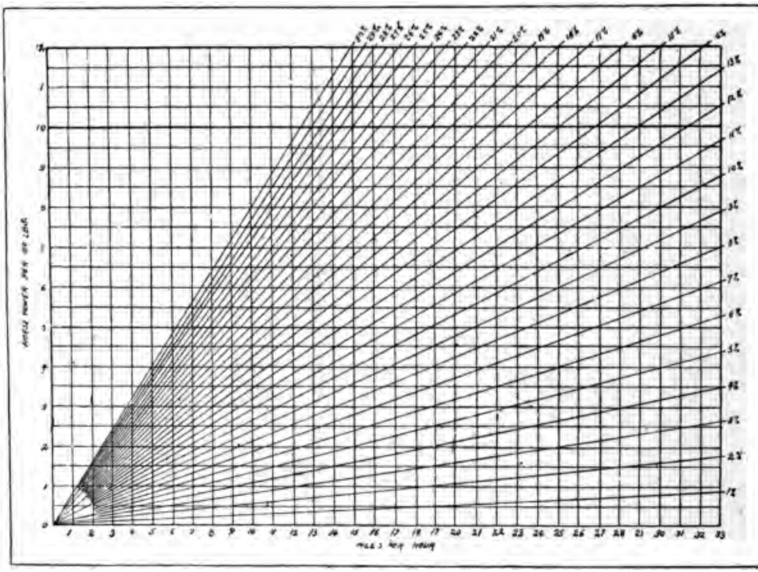

Fig. 9.—Diagram showing relation of speed of vehicle to traction, percentage of gradient, and horse-power under various conditions.

same horizontal line with the diagonal line 4—1, representing the ratio of the speed of the motor to the drive wheel, and follow vertically down to the bottom of the chart, where the revolutions per minute, 630, may be read.

The ratio of speeds may obviously be found in a similar manner if it is desired to run the motor at a certain speed.

To ascertain the power required per hundredweight of the vehicle and its load, it is necessary to know or assume the traction and the gradient. The traction is represented on

Fig. 9 as a certain percentage of each hundredweight of the vehicle. For instance, to find the required horse-power for a vehicle going at 15 miles per hour when the traction is 10 lbs. per hundredweight, or 10 per cent.

The horizontal line at the intersection of the lines representing 15 miles per hour and 10 per cent. is 0·4 or 0·4 horse-power per hundredweight.

If the weight of the vehicle and its load is 6 cwt., then the total horse-power required is $6 \times 0{\cdot}4 = 2{\cdot}4$ horse-power. If in the above case the vehicle is ascending a grade of 5 per cent., add together the 10 per cent. and gradient 5 per cent., and solve as before. The result will be 6 horse-power per hundredweight, or $6 \times 0{\cdot}6 = 3{\cdot}6$ horse-power instead of 2·4, as previously found.

The chart may be used conversely. For instance: At what speed can a vehicle and load weighing 8 cwt., propelled by a 4-horse-power engine, ascend a 15-per-cent. grade, traction being taken as 10 per cent.? The sum of $10 + 15 = 25$ per cent.

The horse-power per hundredweight $= \frac{4}{8} = 0{\cdot}5$ horse-power. At the intersection of the lines representing 5 horse-power and 25 per cent. resistance, is the corresponding speed of 7·5 miles per hour—the result sought.

When descending a grade subtract the percentage of gradient from the traction and proceed as before.

A transparent ruler laid along the diagonal lines will prevent confusion when solving problems on the charts.

CHAPTER IV

LIGHT PASSENGER VEHICLES

General Observations—Petrol Cabs—Various Examples of Petrol Cabs—Electric Cabs—Efficiency of Electric Cabs—Examples of Electric Cabs.

GENERAL OBSERVATIONS

THE lighter class of passenger vehicles adapted for business purposes comprise, as has been already mentioned, hackney cabs, and small omnibuses, carrying a small number of passengers, and plying for public hire. This is one of the most useful purposes to which the lighter class of mechanically propelled vehicles can be put, and their development towards this end cannot be too strongly advocated. Naturally, the greater number of the makers have hitherto chiefly concerned themselves with meeting the demand for pleasure vehicles which has recently arisen amongst the wealthy classes who have taken up motor-car driving as a new pastime.

It is satisfactory, however, to know that the development of mechanically propelled vehicles for useful purposes is now receiving the attention it deserves, and that the industry will soon be founded on a more stable basis than that of providing high-speed cars at fancy prices.

In spite of the high prices obtained at present for pleasure vehicles, as a general rule their manufacture in this country does not seem to pay. The reason for this is obviously the absence of specialization and of enterprise. In fact, at the present moment, most of the firms turning out motor cars here are rather constructors than manufacturers; they make many patterns of cars, unsurpassed, it is true, as regards design and construction, but hitherto they have failed to give their attention to the turning out of one size and one pattern of vehicle in sufficient numbers to

make its manufacture pay. The advent of a general demand for utilitarian automobiles will change all this, and will bring about the specialization that is required to make the industry commercially successful.

The fitness of the motor to supersede the horse is so obvious that it needs no enlarging upon, and, with proper management, there should be no doubt with respect to the financial success of the former.

PETROL CABS

Up to the present petrol motors and electric motors are the only two powers that have been used for the propulsion of cabs, at least with any degree of commercial success, and of these the first mentioned seems to possess the greater qualifications, and will be therefore first dealt with.

EXAMPLES OF PETROL CABS

The "Leo" Petrol Cab

The "Leo" petrol cab, designed by Mr. Léon Lefebvre, is characterized by a great simplicity of construction. The working mechanism is completely enclosed in a suitable casing, and a transmission is provided, the toothed wheels of which are always in gear. The motor used in this vehicle is a two-cylinder Lefebvre "Pygmée," which is located at the rear of the vehicle.

The efficiency of the Pygmée Motor is high, and it is compact in design, having, moreover, the advantage of being very easy to manage. The engine is a balanced one, the pistons of the two cylinders working cranks placed at 180 degress, and thus greatly reducing vibration. Owing to the high compression employed, the consumption of petrol is low (not above 0·968 lb. per horse-power of motor per hour); the admission valves are opened in the usual manner by the suction action of the pistons, and the exhaust valves are enclosed in boxes, and are operated by cams mounted upon an intermediate shaft.

The motor is provided with an ingenious device for regulating the speed comprising a rod carried by the fly-wheel and connected with a centrifugal regulator. During the revolution of the fly-

wheel this rod is forced from right to left against a spring, which latter can be adjusted, as regards tension, by means of a thumb screw. Should the speed of the motor exceed the maximum determined upon, the pull of the above spring will be overcome and the rod will be moved so as to close the exhaust valve on one cylinder and prevent the escape of the burnt gases therefrom, the piston drawing a charge into the cylinder on the next stroke; and should this action be insufficient to reduce the speed of the engine to within the prescribed limits, any further travel of the rod to the left will operate the exhaust valve of the second cylinder in a similar manner.

The carburettor is constructed with a spiral coil surrounding the ignition burners, and either spirit or petroleum can be employed, in the latter case the spiral tube being arranged within the burner. By means of a special arrangement of the air and vapour admission ports, the gas is caused to whirl so as to form a homogeneous mixture before entering the cylinder, and thus to minimise the risk of failure to explode.

The changes of speed are effected in a very simple manner by an ingenious device comprising a disc having slots in which engage two gudgeons on a slide forming part with fork-pieces, and forced to move in a straight line by grooves. In accordance with the position given to the above-mentioned disc through a horizontal axis, the gudgeons can be brought into such positions that the fork-pieces will operate the engagement of the differential gear in the box with either of four pinions. As the gudgeon wheel remains in engagement with a circular portion of the slot, it will be seen that any failure in throwing any particular pinion into gear when changing speed is rendered practically impossible, and the disagreeable shocks occasioned by such failures are obviated. Transmission from the shaft of the motor to that of the gearing is effected by a loose belt normally kept tight by a jockey pulley on the end of a lever, acted upon by a spiral spring. In order to disconnect the motor and gear shaft, it is only necessary to operate the above jockey pulley lever through a pedal lever, so as to compress the spiral spring, and by thus removing the pressure from the belt to allow of its slackening and slipping on the faces of the pulleys on the shafts.

Steering is effected by a vertical shaft operating to turn the front steering wheels round their pivot, which shaft passes through

another hollow shaft mounted in a tubular piece fixed to the footboard. The hollow shaft is connected through suitable bevel gear with the speed-change device.

The Triouleyre Petrol Cab

The petrol cab designed by Mr. L. Triouleyre is also said to have given excellent results. This vehicle has a double suspension arrangement, and consists essentially of two distinct parts, viz. first, the frame upon which is mounted all the mechanism, and which is supported directly on the axles, through suitable springs; and, second, the body of the vehicle, which is connected with the frame by other springs, thus preventing the passengers in the cab from experiencing any vibration.

The motor is an ordinary four-cycle one, revolving at an average speed of from three to four hundred revolutions per minute. It consists of a cylinder with a double casing, an explosion or combustion chamber, and a frame upon which is mounted the driving shaft.

Electric ignition of the intermittent type is used, comprising an accumulator, an induction coil, a sparking plug, and a trembler or vibrator. The accumulator has a capacity of from 70 to 80 hours, and is perfectly tight, being capable when not in use of preserving its electrical energy for several months. It can be easily recharged from a primary battery, or from any available current of two or three ampères. The sparking plug is fixed on the explosion or combustion chamber by means of a metal sleeve or tubular piece, and an internal metal bush or socket having a circular hole or aperture is provided. A platinum stem or rod insulated by a porcelain sleeve from the metal sleeve or tubular piece is connected at its outer end to the terminal to which is connected one of the circuits from the accumulator, the other being connected to the fixed vibrator. The spark takes place between the platinum stem and the shield or cap. One of the two wires from the accumulator connected to the induction coil passes through the sparking plug, and is secured to a terminal mounted on a spring contact piece insulated from the motor, through which spring contact piece a current can pass so long as it is in contact with a cam. When, however, this spring contact piece is no longer in connection with the cam piece, the current is suddenly interrupted and the ignition spark results.

The explosive mixture is automatically introduced into the explosion chamber and the cylinder during the suction stroke of the piston, and the exhaust of the burnt or waste gases during the fourth cycle is effected through a valve operated by an arrangement of gearing, cams, and levers.

The spirit tank has a capacity sufficient to last for a journey of 100 kilometres, and feeds directly to the carburettor, the bottom of which latter is heated by a portion of the exhaust gases. The air is admitted at the upper part, carburetted, and passed to the combustion chamber, together with the additional air taken up during its progress, through wire gauze strainers, which have the effect of causing a more intimate admixture of the air and vapour, and of preventing the occurrence of any back firing. The additional air admitted to the mixture after leaving the carburettor can be regulated by a valve from the driving seat. The exhaust is discharged into a silencer, and the cooling water is circulated from a suitable tank located at the rear of the vehicle.

The belt transmission comprises a double cone keyed on the gear shaft in relation to three pulleys containing the differential gearing, and motion is transmitted from the gear shaft to the rear driving wheels by means of chain gearing. Forward or backward motion can be respectively imparted by means of a straight and a crossed belt, and an arrangement worked from the driving seat admits of the speed being varied as may be desired. The motor can be started from the driver's seat by means of a hand wheel through suitable chain and toothed gearing.

The vehicle is fitted with two brakes, the one operated through a lever and acting on the felloes of the rear wheels, the other through a pedal lever so as to act on a suitable brake drum. The steering is effected through a divided axle.

The Kühlstein-Vollmer Petrol Cab

A pattern of petrol cab introduced some five or six years ago in Berlin is a cab of the hansom type, fitted with the Kühlstein-Vollmer motor tractor, the application of which to the fore-carriage is shown in Figs. 10 and 11.

As will be seen from our illustrations, which represent respectively a side and front elevation of the fore-carriage, the motor and the whole of the driving gear is arranged in a box or casing of a

rectangular shape, the top plate of which is suspended on the pivot plate, the casing being thus located above the centre of the front axle. The top plate of this box or casing is fitted with an internally toothed crown wheel or ring, connected with a hollow

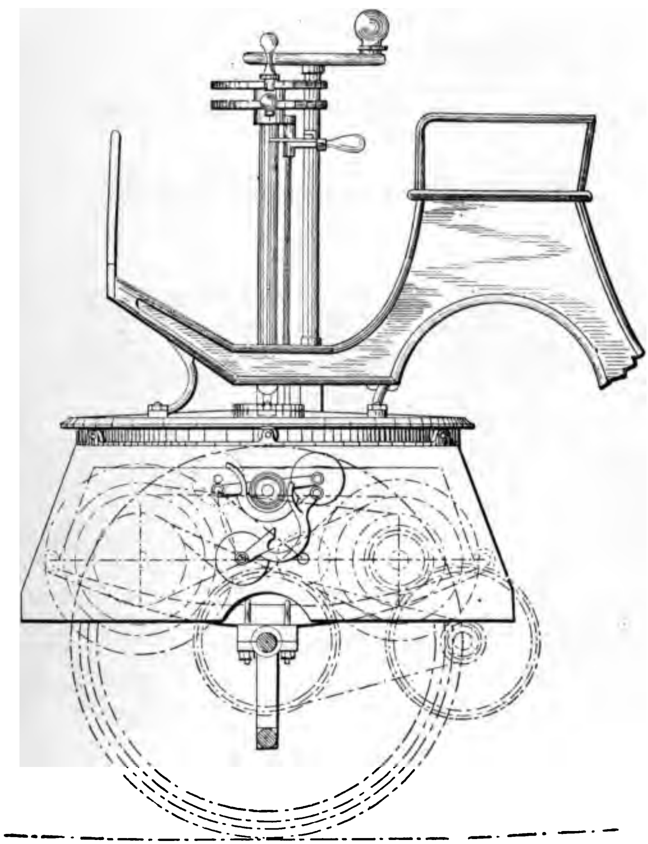

Fig. 10.—Kühlstein-Vollmer petrol cab—side elevation of fore-carriage.

pivot rotatably mounted on the hub of the pivot plate. On a socket in the pivot plate is mounted the steering rod, having a hand wheel at its upper extremity, and at its lower extremity a toothed wheel or pinion, which gears or meshes with the above-mentioned internally toothed crown wheel or ring. To diminish

friction, rollers running on a suitable circular path on the pivot plate are provided.

For the purpose of economizing space as far as possible, the differential gear is mounted directly upon the axle, which latter is

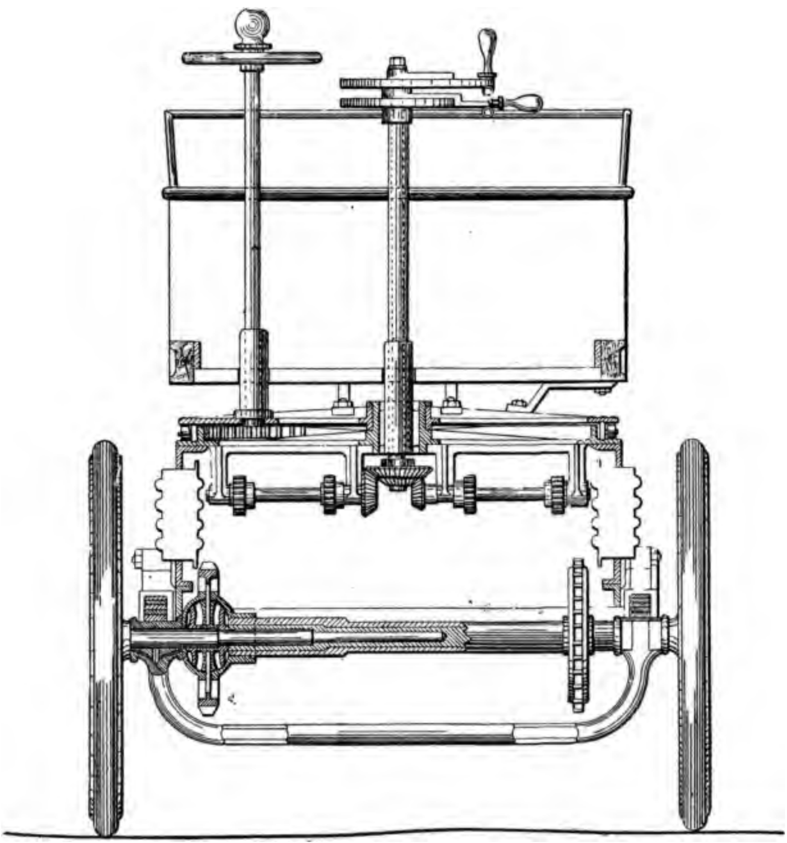

Fig. 11.—Kühlstein-Vollmer petrol cab—front elevation of fore-carriage.

formed in two lengths, the shorter length being fitted within the hollow or tubular portion of the longer length, by which arrangement it is claimed that the axle bearings are relieved of all cross strain, and at the same time the provision of an intermediate bearing is rendered unnecessary. So that an equal load may be

supported through the springs upon each of the axle bearings, power is transmitted through the chain wheels in such a manner that both of them act simultaneously upon the bevel pinions of the differential gear, this action being effected by means of a sleeve mounted on the longer length of axle. The axle bearings being constructed in two parts, enables the two lengths of axle to be inserted, and the upper portions of the bearings which form straps are each connected respectively with one of the springs by which the casing and fore part of the vehicle are carried. The lower portions of the axle bearings are connected by means of a bent shaft, which gives the necessary rigidity and maintains the distance between them constant in a transverse direction. Annular lubricators supply the requisite lubrication.

The motor is arranged in the left-hand side of the space shown in Fig. 11, and is of the ordinary horizontal double-cylinder petroleum spirit type, provided with electrical ignition. Two speeds are provided, and the transmission is by belts which normally run slack, but either of which can be tightened when desired by means of a jockey pulley. These jockey pulleys, together with the operating levers, are carried upon the top plate of the casing.

Through the top plate of the engine-box, at the point at which it is pivoted, is passed a hollow pin or pivot extending into the pivot plate at its centre, so that when the fore-carriage is turned it will be capable of angular displacement relatively to the top plate. Within this hollow pin or pivot are arranged the vertical tubes by means of which the regulation of the motive power is effected. By means of this arrangement it will be seen that the vertical tubes will turn with the top plate during the rotation of the latter, and that the transmisson of the regulating action upon the under frame, which is itself capable of turning, is rendered possible without necessitating any complicated mechanism, at the same time that the driver is able to see the position of the fore-carriage with regard to the vehicle. The above-mentioned vertical regulating tubes are enclosed in an outer tube or sleeve that is rigidly fixed to the hollow pin or pivot of the top plate of the engine-box, and the outermost of the vertical regulating tubes is connected with the lowermost operating lever shown on the left-hand side of Fig. 11, the inner vertical regulating tube being rigidly attached to the other operating lever. At the upper end of the outer tube or sleeve are provided locking discs for these levers. At the

lower extremities of the vertical regulating tubes are mounted bevel or mitre pinions, by means of which the two horizontal shafts shown journalled in the top plate can be rotated by turning one of the operating levers to the right or left, as the case may be.

This arrangement admits of pairs of tension pulleys being operated so that one of them only will act to tighten the belt and give the desired ratio of transmission, the other tension pulley of the pair meanwhile remaining motionless. The pairs of tension pulleys are each mounted upon levers pivoted at opposite points upon the top plate. When these tension pulleys are disengaged the toothed pinions upon the pinion shaft are out of engagement with the toothed segments connected with the tension pulley levers. Besides this lever the lower teeth of the toothed segments on the levers are elevated somewhat above the teeth of the operating segmental toothed pinions, inasmuch as the noses upon the tension pulley levers are supported upon the concentric portion of the cam-shaped hubs or bosses of these segmental toothed pinions.

By rotating the pinion shaft to the left hand, for example, through the uppermost hand lever, the nose of the tension pulley will fall along a reduced cam-shaped portion provided on the toothed wheel hub or boss, and the segment falling in gear will displace one of the tension pulleys. Meanwhile the other tension pulley will remain fixed, because its nose continues to slide upon the concentric portion of the hub or boss of the segmental toothed pinion, and is therefore not displaced. On drawing back the operating lever the tension pulley will return to its normal position, and upon continuing to rotate the lever the other tension pulley will become operative and the former one remain fixed. The pair of tension levers connected with the lower hand lever operate in a precisely similar manner. The turntable is of such a construction as to allow of a full lock being obtained.

The London Express Motor Service Petrol Cab

A more recent type of motor cab is the petrol hansom shown in our illustration (Fig. 12), which is a direct reproduction of a photograph of a cab, which is one of a number placed upon the streets of London about a year ago by the London Express Motor Service, of 37, Walbrook, E.C.

This petrol hansom is a well-designed vehicle, of elegant appearance, and it seems to possess every element requisite to ensure

its becoming a favourite mode of conveyance. It will be observed that the driver sits in front of the passengers, but slightly on one side, so that the view of the latter will not be materially obstructed by him. The cab is, moreover, appreciably larger than the common type of horse hansom, and is fitted with an extra drop-down seat placed alongside that of the driver, so that a third passenger can be comfortably carried when desired. When not in use this seat can be folded up so as to be out of the way. A handy form of spring attachment admits of the glass front being operated by the persons occupying the vehicle, and a distance indicator fixed within the cab allows of their seeing the exact

Fig. 12.—The London Express Motor Service petrol cab.

distance travelled, thus avoiding disputes in that direction. At the rear of the cab bed, and beneath the seat, is a boot, in which such luggage as bags, portmanteaus, etc., can be carried.

The cab is provided with motive power in the form of a 12-horse-power internal combustion engine of the Aster type, which is governed and set to run at a slow rate of speed, and the power is transmitted from this engine through a gearing of the Panhard type to a cardan driving axle. In order to obtain the utmost possible efficiency, and also to reduce the chance of side-slip to a

minimum, the distribution of the weight has been very carefully studied, and so as to allow of the vehicle possessing high hill-climbing powers, and likewise to prevent the driver from running it at an excessive speed upon the level at any time, the driving wheels are geared down low. The full limit of speed on the level is about twenty-six miles an hour.

The Aster petrol motor is built in two patterns, the one being solely water cooled, and the other one being provided with a mixed system of cooling. In one type of Aster motor flanges are cast on the cylinder head and valves, and copper flanges, which are found to be greatly superior to iron ones, are arranged round the cylinder. The Panhard transmission gear consists of a friction coupling on the motor shaft, which is normally in gear with a main shaft carrying four pinions. Four toothed wheels gear with these pinions, and are mounted on an auxiliary shaft located immediately under the main shaft, which latter shaft carries at its extremity a bevel pinion, with which the one or the other of the two pinions on the differential gear can be caused to gear or mesh, in accordance as the forward or backward movement of the vehicle is desired. The disengagement of the pinions effects the stopping of the vehicle. The four toothed wheels on the lower auxiliary shaft can be thrown into or out of gear with the pinions on the main shaft by the moving of a sliding sleeve or coupling box. From the above it will be seen that it is not necessary to employ the friction coupling for the purpose of stopping the vehicle, but it can be used when desired to interrupt communication between the motor and the transmission gear in cases of emergency, or whenever it is desirable or necessary to stop the vehicle suddenly. The main purpose of the friction gear, however, is to allow of smooth starting, and to prevent jarring when changing from one rate of speed to another. The chain wheels gearing on to the driving wheels are carried by the differential shaft.

ELECTRIC CABS

For use in towns on smooth pavements, and where only moderate gradients have to be negotiated, electricity is an ideal power. It is cleanly, can be handled by any one without special skill, is flexible, silent, and entirely free from vibration and odour.

On the other hand, however, the battery is a source of trouble. If improperly charged, rapid deterioration will be the result. Charging and discharging at regular intervals, whether used or not, is imperative, otherwise chemical action sets up and rapidly reduces the efficiency. Proper attention must be paid to the controller, the contacts must be properly cleaned, adjusted, etc. The general mileage of electric-driven vehicles is from twenty to forty miles on one charge.

Some few years ago electric cabs were put on the streets of both London and Paris, but for various reasons failed to be commercially successful. According to a statement made by the proprietors, as given in *Le Chauffeur* at the time, the chief reason for their failure in Paris was owing to the defective accumulators, and they stated positively that the service would be renewed when a suitable accumulator was available. This was, however, says the above-mentioned publication, only a part of the trouble experienced. When deciding on the design of vehicle to employ for the service in question, the principal points kept in view were the easy removal of the accumulators, and the efficient charging of same. Unfortunately, the company took as their model an English electric cab in which the batteries were suspended by chains, although there existed at the time at least one efficient electrically propelled vehicle that might have been preferably adopted. Another error was made in constructing the charging station at a distance of four miles from Paris, so that each cab had to make daily a double journey of four miles each way to and from the charging station; that is to say, run eight miles a day without any return. From the above it will be seen that the failure of this electric cab service was due more to errors in judgment, and to the bad management of the executive, than to any existing defect in electricity as a motive power.

The London Electric Cab Company placed a number of electric cabs upon the streets of London in the year 1898, and continued the service until near the end of 1899. After a break in the service, owing, it was said, to the vehicles being withdrawn for repairs and alterations, they were again placed upon the streets, and ran for a brief space of time, when the company was finally wound up, and the whole plant and stock sold early in 1900.

EFFICIENCY OF ELECTRIC CABS

The most important point in electrically driven cabs is the duration and capacity of the battery; indeed, any opinion, to be reliable, should be founded on the condition of the battery after the vehicle has been in actual practical work during a considerable period of time, say, at least six months.

In the case of an electrically propelled cab, the exigencies of bad roads, steep gradients, and heavy loads unavoidably entail the necessity of drawing heavily and suddenly upon the store of electricity in the accumulator, and these sudden and severe discharges have the effect of causing a certain amount of expansion of the grids or plates to take place, with a consequent loosening of a certain proportion of the paste from them, which loosened paste, being carried out by the motion of the acid, remains in suspension in the latter between the plates, with the result of internal short-circuiting. Should a cell be short of acid room the grids will be expanded to such an extent by over-heating that they will not again contract enough to form connection with what paste remains, and besides, as has been pointed out by Professor Hele-Shaw in his paper on "Road Locomotion," read before the Institution of Mechanical Engineers, splashes of acid are the cause of much more loss than is usually suspected. The practice of grouping cells in parallel, says the same authority, is open to the serious objection that if a cell on one side becomes dead or is reversed, those on the other expend energy in re-establishing equilibrium. English, French and American tests prove that after six months' running, even under the most careful supervision, practically all secondary cells must have the positive plates repasted or renewed at a cost not below one-fifth of the original outlay; while in many cases, as commonly used, they are practically worthless at the end of this period, or even sooner. So long as a range of 40 miles per charge, at speeds not exceeding 10 miles per hour, meets the requirements, electricity, at a cost of not more than 2d. per B.T.U., is at least on a par with steam or oil even for heavy traffic. Where these limits are exceeded, electricity is inadmissible. Distances greater than 40 miles, and speeds greater than 10 miles an hour, involve prohibitive dead weight and excessive discharge rates.

Although, as above intimated, the cells of a battery deteriorate

very rapidly if the vehicle be driven at high speeds, very surprising results have notwithstanding been attained with electrically propelled vehicles. In 1899, Jenatzy, in a vehicle not specially constructed for speed, covered a kilometre at the rate of 50 miles an hour; and in the same year the Count Chasseloup-Laubat, in an ordinary Jeantaud electric car, obtained 57⅝ miles an hour; whilst later on in the same year Jenatzy, in an electrically propelled carriage especially built for the purpose, succeeded in running a kilometre at the rate of 65⅜ miles an hour. It must be noted that the above speeds were obtained with running starts; the average speed made with standing starts was, however, 46½ miles an hour, and the results obtained amply proved that, as regards high speed, electricity could be made to give very remarkable, though not practical, results, the latter being demonstrated by the fact that even after the short runs made of two kilometres the batteries were in each case to all intents and purposes destroyed in the run, and the vehicles had to be towed home.

EXAMPLES OF ELECTRIC CABS

The Bersey Electric Cab

The above cabs were constructed from the designs of Mr. W. C. Bersey, and, as the first hackney motor vehicle actually in use for upwards of a year in the public service, the details of their construction are of considerable interest. The vehicle in question partakes in construction of the form of a closed coupé, and has a capacity for two inside passengers and the driver, whose seat is mounted on a raised front platform, the weight complete, with the storage battery, being about two tons. The motor mechanism is carried upon a lower rectangular-shaped frame constructed of angle-iron bars, mounted on the axles through leaf springs, and the body of the cab is suspended from this frame in such a way as to avoid as much as possible all shocks and vibration. The driver's seat is, as already mentioned, mounted on a platform, and this platform is carried upon a raised framing rigidly connected to the lower frame of the vehicle. The wheels are shod with solid rubber tyres. The storage battery is placed in a box suspended from the underframe, which latter arrangement is claimed to admit of its being easily detached and replaced by a

newly-charged battery. The battery consists of 40 E.P.S. cells capable of supplying current at an average pressure of 80 volts. The average discharge on the level would be about 30 ampères, and as the battery has a capacity of about 150 ampère hours, one charge should therefore be sufficient for a run of from 25 to 30 miles, in accordance with the condition of the roads.

The motor and driving gear are mounted on the rear part of

Fig. 13.—The City and Suburban Electric Carriage Company electric hansom cab.

the lower frame, and are covered in by the rear-box of the cab body. Toothed gearing transmits power from the motor to a counter-shaft, on which latter is mounted the differential gear, and chain gearing transmits power from this counter-shaft to the axle of the rear driving wheels.

The speed of the motor can be regulated by means of a controller, which can be operated by means of a lever placed at the left-hand side of the driver. There are four forward speeds, the highest being about nine miles an hour, and one reverse

speed motion of two miles an hour. The same lever also admits of the application of an electric brake, which latter is formed by the reaction of the motor upon itself as a dynamo. To render it impossible for any unauthorized person to start the vehicle when left by the driver, a plug key, which admits of the main circuit between the battery and the motor being broken, is provided in the box situated beneath the driver's seat. There are also provided two ordinary band brakes acting on brake drums connected with the rear wheels of the vehicle, which brakes can be applied by means of a pedal in front of the driver, the pedal also acting at the same operation to first automatically break the electric circuit, and thus to place the motor out of action previously to the application of the brakes.

The steering mechanism consists of a hand wheel, operating through a set of toothed gearing, and a locking plate connected to the fore axle of the vehicle.

The motor is of the Lundell type, the armature being of the laminated drum pattern, and there are two sets of windings connected to independent commutators located at the extremities of the spindle of the armature. The field magnet is constructed of a form calculated to reduce the amount of the demagnetizing effect of the armature upon the field as far as possible, and thereby maintaining a maximum degree of constancy, even when the load on the motor varies through a very wide range. This arrangement allows of the brushes being set practically once for all, and does away with the necessity for their being adjusted between no load and the highest load to which the motor can be subjected, to obviate sparking. The field magnet is formed of two mild steel castings, and forms a cylindrical shell surrounding the armature, the two parts thereof being connected together by bolts, and the ends closed by covers having conical projections, which latter surround the commutators, and at the extremities of which are located roller bearings which support the armature spindle. The poles of the field magnet are surrounded by a coil also formed in two independent parts, like that of the armature winding. Carbon brushes are used, which brushes are set symmetrically between the pole tips of the field, and are caused to press against the surfaces of the commutator under the action of springs.

This motor, which is capable of developing 3-horse-power at

the ordinary speed of the cab, is bolted to a cast-iron bed plate through four feet or lugs formed integral with the end covers.

The various speeds of running are given to the cab by forming different combinations between the two independent windings of both the armature and field, a resistance coil and the storage battery.

The controller consists of a drum or cylinder constructed of wood, and mounted upon a spindle journalled to an iron tray or bed-plate, upon which the several parts are mounted. This cylinder is divided into five principal parts by vulcanite rings, and brass contact pieces are secured on its periphery by means of countersunk screws. In some cases these contact pieces are electrically connected together, and in others they are insulated from one another in such a manner as to admit of various combinations of the battery and motor windings by forming interconnection of the brushes of the controller, which are connected by means of suitable binding screws placed upon a wooden bar, and insulated wires, with the storage battery, motor windings, and the resistance coil. The positive terminal of the battery is connected to the first, or number one, of the controller brushes, and the negative pole of the battery to the eleventh, which is the last of the brushes. The third brush is short-circuited with the first brush through the resistance coil, which, together with the controller, is enclosed in the box beneath the driver's seat, whilst the second brush is electrically connected to one extremity of one of the windings of the field magnet, the other extremity of this winding being connected to the fifth brush. The remaining field-winding is similarly connected to the fourth and seventh brushes, and the sixth and ninth brushes are connected to the brushes of the commutator at one extremity of the armature, and consequently to the windings of this latter. The eighth and tenth brushes are in like manner connected to the brushes of the commutator at the other extremity of the armature, and consequently to the windings thereof.

The controller drum or cylinder can be moved by means of a hand lever, toothed segment, and pinion, and the drum or cylinder can be moved into eight distinct positions, in each of which it is held spring tight by the engagement of one of the teeth or projections on an eight-toothed ratchet, and a spring-actuated roller pawl arrangement. The contact pieces on the periphery of

the drum or cylinder are so placed that the above eight positions of the latter will give eight different combinations of the eleven controller brushes, providing respectively four different forward speeds, a breaking of the circuit, two combinations disconnecting the armature windings from the battery and sending a current through the field-windings, thereby giving rise to a powerful braking action, and finally a combination by which the direction in which the armature is revolving can be changed, and consequently backward movement can be imparted to the vehicle.

The motor is mounted upon a bed-plate, which is secured to the under-frame of the vehicle by longitudinal iron bars bolted to cross bars uniting the side pieces of the under-frame. Power is transmitted to the rear wheels by means of chain gear from a counter-shaft, to which the motor is geared by toothed gearing, and an arrangement of differential gearing.

The steering is effected by means of a hand-wheel at the top of a pillar provided in front of the driver's seat, and on the spindle of which hand-wheel is fixed a worm which gears with a worm-wheel on the top of a vertical spindle passing down the steering pillar, at the lower end of which spindle is a toothed pinion which gears or meshes with a toothed wheel, forming part of the locking gear that is supported by the front axle of the vehicle. This toothed wheel is connected by four arms with a cylindrical boss, which guides the turning movement of the wheel round a central fixed cylinder integral with the upper fixed half of the locking gear, the friction between the locking plates being reduced to as low a point as possible by a ring of balls running on ball races formed on the locking plates.

Two band brakes, actuated by a pedal, are also provided, in addition to the electric brake already mentioned. The depression of the pedal first operates to break the connection between the battery and the motor through the opening of a switch placed in the main circuit, power being thus cut off before the application of the brakes is made.

The Morris and Salom Electric Cab

Electric cabs built by Messrs. Morris and Salom, of Philadelphia, U.S.A., for the Electric Vehicle Co., of New York, have been sent to both London and Paris, and run on the streets of these

cities with more or less success. The designs of these cabs differ materially from that of the cab of the London company, which has just been briefly described. An important improvement in the details of construction is the carrying of the battery in the main body of the cab, thereby avoiding the jolting that was found to be so fatal in the case of the London cab. The driving [is

Fig. 14.—The City and Suburban Electric Carriage Company electric cabriolet.

effected, moreover, by means ot single gearing; pinions on the extremities of the spindles of the two motors, which are of the Westinghouse type, meshing with internally toothed rings fixed on the driving wheels, which in this case are the front ones; and as the motors are independent, no differential gearing is required.

The trays of batteries are shoved into the body of the cab from the rear, and, by an ingenious arrangement, the contacts are made automatically as the batteries are pushed into place. To effect this purpose the batteries are permanently connected to contact pieces provided on the trays, which, so long as the driver's switch is open, are out of circuit.

The wheels are made of wood, and are of the artillery pattern, fitted with pneumatic tyres, 5 ins. diameter, inflated to a working pressure of about 60 lbs. per square inch. Together with the storage battery, which latter weighs something over 11 cwts., this cab weighs 20 cwts., or just one ton.

Space does not admit of entering fully into the details of construction of the cab; the following, however, are the most salient features:—

The vehicle has no separate under-frame, as all the machinery is mounted upon the carriage axles, the requisite attachments being made to the transoms of the body of the vehicle. By an arrangement consisting of a pivoted projection upon the fore-axle, the distance of the spindles of the armature and their toothed pinions is kept constant, whatever may be the movement of the tail of the motor. This latter is hung by means of rods to the body of the vehicle, rubber buffers being provided to prevent undue shocks at the end of its range of movement in each direction. The internally toothed rings are secured, as has been already mentioned, to the rims of the front wheels. These latter are 36 ins. in diameter, and the hubs are fitted with roller bearings, with end-thrust balls and cones, the rollers being about 5½ ins. in length, and working on steel sleeves on the axle.

The steering axle has steel fork castings receiving the pivoted Ackermann axles, which are placed in positions inclined to the horizon. The above fork castings have extensions to which the hanging links for the transverse springs are connected, which latter support the heavier end of the cab containing the battery box. The front end of the cab is supported upon springs pivoted at their front ends to the framework of the vehicle, and at their rear ends hung from links at the extremities of a transverse spring.

The steering is operated by a lever working longitudinally of the vehicle. There are two band brakes on drums on the shafts of the armature worked by a pedal on the upper end of a lever

connected at its lower extremity to a thin wire rope passing over a pulley and connected to a bar, which latter is in turn connected to the brake levers by two chains. These brakes are normally held out of action by spiral springs.

The battery comprises 48 cells, and is divided into two sections, the series-wound fields of the motors being also placed in sections. This arrangement admits of a number of series and parallel combinations being made, by means of a controller, to effect the three speeds in a forward direction and the reverse movement of the vehicle.

The controller can be actuated by a hand lever located at the left-hand side of the driver's seat, and the speeds given by its operation are 6, 9, and 12–15 miles per hour. It is of the rotary type, and it has eleven contact plates, coupled up by suitable leads. The connections to the reversing and ordinary forward working switch are operated by a pedal, which, under normal conditions, is kept in position for maintaining the switches in contact for the movement of the vehicle in a forward direction. When depressed for reversing the motion of the vehicle, the pedal operates to cut out one set of switch connections, which are pivoted to a rod, and to throw in another set, coupled with the wires of each motor. A socket is provided for a dual plug, to allow of the batteries being charged in position.

The "Draulette" Electric Cab

An electric hansom cab designed to accommodate four inside passengers, besides the driver on the dicky, is the "Draulette," a description of which was given about three years ago in the *Motorwagen.* This vehicle, which is the invention of a Captain Draulette, is of somewhat novel construction. It is mounted on road wheels of the artillery pattern. The entrance is in front, the step being between the two lower front wheels, and the doors are practically similar to the wooden apron of an ordinary horse hansom. The four inside passengers are seated in a semicircle, whilst the driver's seat is located at the back, as is usual in hansom cabs. The power is derived from a battery composed of 44 Fulmen cells, of the type B13, each of which cells contains six positive and seven negative plates. The capacity is stated to be 105 ampère hours, a supply which is calculated to be sufficient

to last for running five hours at a speed of 12 miles per hour, or for a mileage of 60 miles per charging. The accumulators are stowed away in four chambers situated beneath the passengers' seat.

The electro-motor was designed specially for use in this vehicle, and is of the two-poled type, provided with double carbon brushes. In order to allow the electro-motor a certain limited amount of freedom of movement, it is supported at the rear by means of an arrangement of springs and rollers, which is so designed that it does not interfere in any way with the connection with the toothed wheels. A toothed or spur wheel is keyed fast on the spindle of the motor, and gears or meshes with another toothed or spur wheel of larger diameter, which latter is either carried on an intermediate or counter shaft, or is combined with the differential gearing. At each end of the intermediate shaft is provided a toothed pinion, gearing or meshing with an internally toothed ring mounted concentrically with the rear wheels of the cab.

The vehicle has four forward speeds, viz. $2\frac{1}{2}$, 5, $8\frac{1}{2}$, and 12 miles an hour, besides one of 3 miles an hour backwards. As in all the best types of electro-motors, the changes in the rates of speed are effected by changes brought about in the speed of the electro-motor itself, without the use of speed gearing of a complicated nature, the backward motion being, however, effected by the use of gearing of a special form.

The motor is arranged so that it can be employed to act as an electric brake, and the resistance of the circuit can be adjusted in such a manner as to admit of four different brake powers being obtained. An arrangement is also provided by means of which an application of the foot brake by the driver will cause the electric brake to be automatically applied at the same time.

As has been already mentioned, the vehicle is mounted upon four wheels of artillery pattern, the rear pair, which are used for driving, being 50 inches in diameter, and the front pair, which are used for steering, being 30 inches in diameter. The total weight of this electric hansom cab, with accumulators, and loaded with four inside passengers and the driver on the rear outside seat, is about 24 cwts.

The City and Suburban Electric Carriage Company Electric Cabs

The following is a brief description of the two vehicles shown in Figs. 13 and 14, built by the City and Suburban Electric Carriage Company, of York Street, Westminster. The electric hansom cab, shown in Fig. 13, is adapted either for private use or for public service. In the former case the upholstering and fittings would naturally be of a more luxurious nature, and it would be very suitable for a doctor or other business or professional man for making his rounds.

This hansom has seating capacity for two passengers inside, besides the driver. The wheels are of wood and of the artillery pattern, the tyres being of solid rubber, $2\frac{1}{2}$ inches in diameter.

The front wheels are used for steering, and are mounted on Ackermann axles. Several different speeds are obtainable by various combinations of the battery and motor windings, which can be effected through the controller, the operating lever of which is shown on the left-hand side of the driver's seat. The maximum speed is one of 12 miles per hour, and the cab is also fitted with reversing gear, thus enabling it to run backwards on one or more speeds.

The battery is the result of many years' experience and usage under very severe tests in practical work, and is claimed by the makers of the cab to be superior to any hitherto in use. The elements are specially manufactured for the company by the Electrical Power Storage Company, of Great Winchester Street, London, E.C. The battery is capable of propelling the vehicle with its full complement of passengers and the driver for a distance of 30 miles, more or less, according to the conditions of the road surface, gradients, etc., with one charge of current.

Figure 14 shows a cabriolet constructed by the same makers, which is known as the "Essex Cabriolet," and is both a very serviceable as well as a very handsome vehicle, of a type adapted for business purposes or for a pleasure carriage. The vehicle is adapted to seat two passengers inside and one on the driving box beside the driver. The apron is made, as shown, with a deep hollow, so that a lady in evening dress can be seated with perfect comfort and without any fear of crushing or soiling her apparel,

and as the apron, moreover, is hinged at the front of the platform, it obviously allows ample space. By an ingenious but simple arrangement of rods and levers, the operating one being at the side of the driver, the apron can be opened or closed by the latter from the driving box. The front window can be folded up when desired, and the side windows are made to drop. The mechanical construction of this vehicle is similar to that of the hansom cab shown in Fig. 13, and the maximum speed is 12 miles per hour. The vehicle is capable of running 40 miles on one charge of current on hard level roads.

The following particulars apply to both the hansom cab and the "Essex" cabriolet. The wheels are of wood, and heavy artillery pattern, fitted, as has been already mentioned, with solid india-rubber tyres 2½ inches in diameter, the back wheels being 36 inches and the front wheels 32 inches in diameter. Each vehicle has two electro-motors, each of which motors is arranged to drive its own wheel independently, thus enabling differential gearing to be dispensed with, and as the various speeds are obtained by controller combinations, no change-speed gear is required. The battery is in two sections of 24 cells each, or 48 cells in all, and one section of 24 cells is carried in the front part of each of the cabs, and the other section of 24 cells at the back, thereby distributing the weight equally on the back and front wheels. Together with the trays the complete battery of 48 cells weighs about 12 cwts., and the weight of each vehicle, with the battery, but without passengers, is exactly 30 cwts.

CHAPTER V

HEAVY PASSENGER VEHICLES

General Observations — Steam Omnibuses — Examples of Steam Omnibuses—Petrol Omnibuses—Examples of Petrol Omnibuses —Compound or Petrol-Electric Omnibuses—Electric Omnibuses —Examples of Electric Omnibuses.

GENERAL OBSERVATIONS

STEAM-PROPELLED road vehicles adapted to accommodate considerable numbers of passengers, that is to say, steam coaches or omnibuses, as well as lighter steam carriages adapted for fewer numbers of passengers, occupied the attention of the first experimenters in mechanical road locomotion, and that these classes of vehicles were brought by them to a considerable degree of perfection is proved by the steam coaches and carriages of Griffiths, Brunel, Gurney, Hancock, Summers and Ogle, Church, Dance Macerone, James, Hill, Yarrow and Hilditch, Rhodes, Holt, Knight, Catley and Ayres, Todd, Randolph, Grenville, Mackenzie, Blackburn, Thompson (the first inventor of the pneumatic tyre), and others.

Indeed, as has been already observed, there can be no reasonable doubt but that the steam road carriage would have been perfected many years ago if the very success of the earlier examples had not raised up a host of enemies against them, whose active opposition, combined with the attraction of enterprise and capital to the railways, then in their early infancy, and the condition of the roads in this country, which was even more deplorable then than now, finally stifled all efforts in that direction, and so the matter rested in abeyance until again taken up within the last few years.

The revival of the movement in favour of mechanically propelled vehicles, which commenced some fourteen years ago, as might be expected, again met with a large amount of opposition from prejudiced and interested persons, and indifference from the general public, and that although the many advantages possessed by this type of vehicle should be obvious to any person who gives the matter impartial consideration. This opposition, however, has now, owing largely to the wide and progressive views of our popular monarch, been to a great extent overcome, and most

people are prepared to admit the utility of the mechanically propelled vehicle, at least for purposes of heavy passenger and goods traffic on the public roads.

An important factor in the running of any line of motor omnibuses is the condition of the road surfaces, and to ensure success these will have to be maintained in far better condition than is at present usually the case in this country. As it is, several services of motor omnibuses have already had to be abandoned owing to the shocking state of some of the main country roads in Ireland; and many of the English main roads are in no better, if as good, a condition. The authorities in charge of roads should see that it is obviously to their advantage to encourage the extension of the use of mechanically propelled vehicles, inasmuch as the damage done by them to the road surfaces is far less than that of horse traffic, owing to the absence of the pounding and tearing action of the horses' hoofs, and there is also the saving that would be effected in the cleansing of the streets, owing to the absence of droppings, which, in crowded thoroughfares, constitutes such a serious item; besides that, the condition of the streets and roads, from a sanitary point of view, would be incomparably superior.

Mechanically propelled omnibuses are successfully operated by all three of the powers mentioned in the introduction to these articles, viz. steam engines, internal combustion engines, and electricity, the first of these being that which, as just mentioned, was used by the pioneers in the movement, and which, for this reason, will be first dealt with.

STEAM OMNIBUSES

Before proceeding to give a few specific examples of the most recent designs of steam omnibuses, which, if not perhaps quite perfect with respect to some of the minor details of construction, certainly, so far as the main features are concerned, have successfully solved the problem of omnibuses propelled by this power, it will be interesting to note the results obtained with such passenger vehicles a few years back. The particulars contained in the following table have been abstracted from a table of results obtained with some heavy steam vehicles, and given by Mr. John S. Thornycroft, F.R.S., in a paper read before the mechanical section of the British Association at the Dover meeting in 1899.

RESULTS OBTAINED WITH STEAM PASSENGER VEHICLES.

Vehicle.	Weight and loads—tons. Tare.	Fuel and water.	Net.	Gross.	Ratio, net tare.	Speed, in miles per hour.	Maximum gradient climbed.	Engine cylinders and stroke.	Fuel.	Gauge, with pressure in pounds.	Heating surface.	Grate area.	Evaporation in pounds per pound of fuel.	Per cent. of efficiency of boiler.	Pounds of water per gross ton-mile.	Pounds of fuel per gross ton-mile.
										sq. in.	sq. ft	sq. ft.				
Weidknecht steam 'bus for 16 persons and luggage	4·7	0·67	1·5	6·87	0·32	9	—	4·92 ins. and 4·92 ins. by 4·92 ins.	Coke	170	64	3	6·5	58	10·1	1·56
Scotte steam 'bus for 12 persons and luggage ...	4·13	1·03	1·18	6·34	0·286	6·5	—	4·3 ins. and 4·3 ins. by 4·5 ins.	Coke	170	120	1·4	5·3	47·3	11·4	2·16
Serpollet steam tram, with trailer, 100 persons, and luggage	11·62 with trailer, staff, fuel, & water		7·56	19·18	0·65	—	1·20	5·9 ins. by 5·9 ins. by 6·3 ins.	Coke	75–250	43	3	6	53·5	—	—
Scotte steam 'bus, with trailer, for 26 persons with luggage	5·87 'bus only	1·02	1	7·87 'bus only	0·171	7·5	—	—	—	140	120	—	5·3	47·3	11·4	2·16
De Dion steam 'bus, 16 persons and luggage ...	4·21	0·74	1·10	6·05	0·262	8·5	—	—	Coke	200	60	1·9	6·2	55·3	6·8	1·1
Martyn's steam 'bus for 22 persons and luggage	2·975	0·5	1·65	5·13	0·554	15	1·15	5 ins. and 5 ins. by 7 ins.	Coke	125	—	—	—	—	—	—

An examination of this table shows that the results obtained by the De Dion omnibus, with regard to fuel and water consumption per gross ton-mile, were appreciably less than those of the other vehicles. The reason for this smaller water consumption is to be found in the high amount of superheating employed. As regards fuel consumption, it should be borne in mind that this item constitutes but a comparatively small part of the total running expenses of a mechanically propelled vehicle—according to an estimate made by Mr. Thornycroft, not more, indeed, than 10 per cent. of the total running cost—and is not, therefore, a matter of such vital importance as supposed by some people.

EXAMPLES OF STEAM OMNIBUSES

Clarkson Steam Omnibuses

Figs. 15 and 16 show a small steam omnibus and a public service steam omnibus built by Messrs. Clarkson, Limited, of Moulsham Works, Chelmsford, a firm who have established a reputation for the manufacture of high-class steam cars, and whose liquid fuel burner is so well known to all those interested in the subject of steam-propelled vehicles.

The smaller of the above omnibuses, shown in Fig. 15, is adapted to seat 8 persons, and is suitable for station or long-distance touring work, etc. Under most severe trials, this vehicle has proved to be a thoroughly trustworthy and reliable vehicle, one of a practically similar construction to that illustrated having run four thousand miles without either repair or breakdown of any description.

Amongst the features of construction worthy of special notice, mention may be made of the following : There is not a single lubricator or oil cup to replenish and adjust, the whole of the working parts, both of the engine and gears, being completely enclosed in an oil-tight case, the bottom of which forms an oil well, from which the lubricant is pumped to all the joints and working parts in rotation, the oil draining back into the oil well and being filtered and pumped over and over again, a gallon of oil lasting in this manner for 1000 miles before requiring replenishing. The burner is automatically controlled by the steam pressure, thus enabling the vehicle to stand for hours if required

under steam, and be ready for starting immediately. Heavy oils can be perfectly burnt without any appreciable amount of smoke

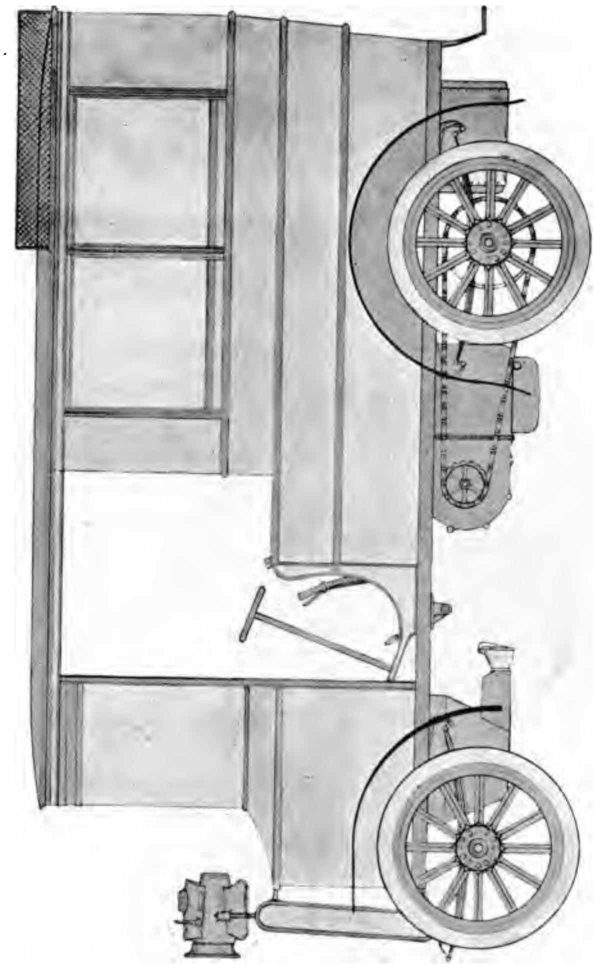

Fig. 15.—Clarkson 8-seated station steam omnibus.

or smell, a number of different grades of paraffin being capable of being used without alteration to the burner. The water-feed is automatic, and a simple, strong form of controlling gear, which it

is practically impossible can become deranged or inoperative, is provided.

The engine develops over 20 brake horse-power, and the

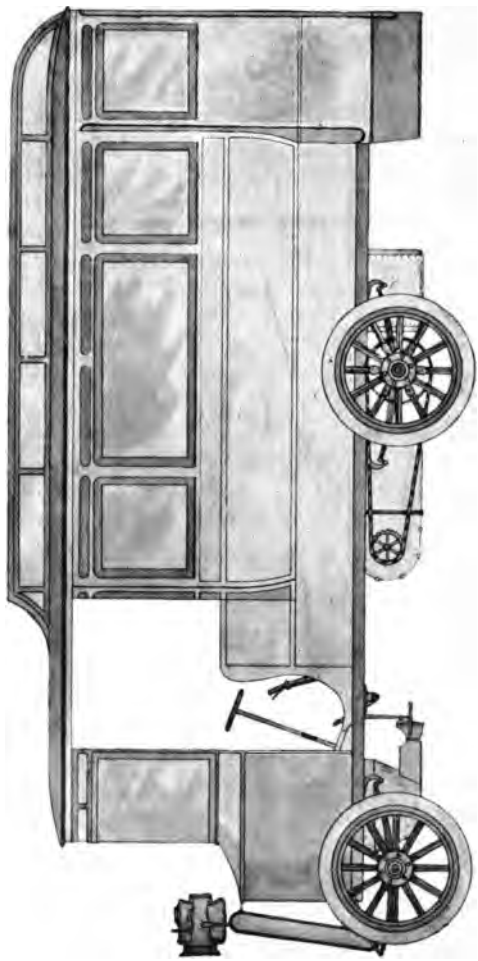

Fig. 16.—Twelve to twenty-seated steam omnibus.

steam is condensed, the water of condensation returning to the feed tanks, where it passes through filters, thus enabling the vehicle to run over 100 miles on one supply of water and oil.

G

The average speed is about 16 miles an hour, and the fuel consumption is about 1*d.* per mile, the consumption of oil being one-sixth of a gallon per mile, and that of water $1\frac{1}{2}$ gallon per mile when not condensing; when condensing, 0·283 of a gallon per mile is found sufficient. The amount of water carried for a run of 120 miles is 34 gallons. Either "Turner" 3-in. solid rubber tyres or "Bailey" non-slipping pneumatic tyres are usually fitted.

The larger public service steam omnibus illustrated in Fig. 16 is built in several sizes, adapted to carry respectively 12, 16, and 20 passengers.

A public service steam omnibus of the above type, adapted to seat 16 passengers and the driver, or 17 persons in all, has been built for the Torquay and District Motor Omnibus Company. This omnibus, before delivery, was subjected to a very successful test, of which the following are the particulars:—

The number of persons carried on the test was 17. The length of the run was 32 miles, during which no involuntary stops were made. The test hill negotiated was a severe one, the steepest pitch being 1 in 6·5; nevertheless, a speed of over 6 miles per hour was maintained, the average speed made throughout the journey of 32 miles being $13\frac{1}{2}$ miles per hour. The grade of fuel used was Russian petroleum, "Rocklight" brand, and the consumption during the test was 6·75 gallons. The consumption of water was 16 gallons.

The above oil consumption made the cost of fuel per mile during the test work out at 1·05*d.*, and the cost of fuel per passenger per mile at $\frac{1}{16}$*d.*

The omnibus was subsequently run by road from Messrs. Clarkson's works to Torquay, covering the journey without an involuntary stop, although the road conditions were very severe, and in some parts the floods were out, there being a depth of fully 2 feet of water on the highway. This vehicle has since done excellent service, carrying between four and five thousand passengers daily.

The following is the specification of the above omnibus:—

Body.—'Bus body is built of well-seasoned wood, with seating accommodation for sixteen passengers, in addition to the driver; twelve seats being in the body of the 'bus, two at the rear platform, and two in front next to driver. Easy steps are fitted at the rear.

The rear platform is closed in, so as to form the opening of the doorway, and fully glazed. Brass handrails are provided to the steps. The side and front windows are made to slide up and down, the frames being constructed of mahogany, varnished in the clear wood, and fitted with plate glass securely fixed. Handrails are provided along the roof on each side of the corridor. Circular sliding plate glasses and frames are fitted in front of the driver. Pressed steel wings are fitted to the front wheels. The 'bus is finished in the natural wood, varnished. The upholstery is of the best leather, with plain spring cushions, and trimmed to waist line.

The Chassis is composed of the several parts enumerated below:—

The Frame.—Formed of mild steel rolled channel, bent at the corners, and riveted with transverse members for the support of the engine and other details of the machinery.

Axles.—Of the best construction, with case-hardened bearings; the boxes accurately machined out and bushed with bronze.

Boiler.—The shell of the boiler measures 22 inches in diameter by 18 inches long, and $\frac{9}{32}$ inch thick, and is constructed of mild steel without longitudinal seams, being pressed out of the solid plate. The tubes are of weldless solid drawn steel, $\frac{9}{16}$ inch outside diameter, 20 g. thick, expanded in the top and bottom plates, and, in addition, beaded over, so that each tube forms a stay. The boiler is tested by hydraulic pressure to 750 lbs. per square inch, and by steam to 500 lbs. per square inch, and is fitted with twin safety valves, set to blow off at 400 lbs., an automatic regulator set to 300 lbs. to control the burner, and an extra large Klinger gauge to indicate the water level, all the necessary gauges and fittings being of the highest construction.

Draught.—The draught is natural, and quite independent for its action upon cowls, steam jets, and baffles, and a sheet-steel flue carries the products of combustion clear of the roof.

Superheater.—A steel superheating tube is fixed close beneath the lower tube plate of the boiler.

Burner.—This is the latest and most improved form of "Clarkson" burner, capable of burning any grade of paraffin oil, whether Kerosene, Rocklight, Testefas, etc., and is fitted with patent express starter, which needs no spirit. It is automatically regulated by the steam pressure at 300 lbs., and entirely

self-contained, being enclosed in a sheet-steel burner box, lined with nickel. An inspection door is provided, and also a measuring cup and clockwork fan for the starter. The consumption of the burner is tested to 25 lbs. of oil per hour at a pressure of 40 lbs. The oil is supplied to the burner through a new combination valve, which enables the vaporizer to be readily cleansed by steam, thereby prolonging the life and preserving the efficiency of the burner.

Engine.—Two cylinders, 4 ins. by 4 ins. horizontal, double acting, high-pressure type, slide valves actuated by Joy's gear. The cylinders, piston rings, and valves are of special hard close-grain iron. Piston rods and cross heads are forged solid of steel, with bored guides. Solid-ended and ribbed cast-steel connecting rods, bushed with phosphor bronze. Crank shaft of forged steel, bored hollow, and made in halves, riveted together with steel driving wheel between, and enclosed in a cast aluminium case with sheet-metal panels made removable, the top panel having a circular inspection hole, fitted with a dust-tight but quickly removable lid.

Differential Gear.—The engine drives direct on to a bronze gear ring, encircling the differential gear box, the sides of the box being of cast steel, and the differential gear of the spur type; all six wheels are of phosphor bronze, cut out of the solid and working on hardened steel pins. The differential shafts are of steel, forged solid with the wheels on the inner ends, the outer ends coned and screwed and fitted with three keys for securing the chain sprockets. Each shaft is carried on two double ball bearings, fitted in heavy cylindrical races, hardened and ground to fit, and the two inner bearings take all end thrust. The outer bearings are fitted with ball and oil retainers. Each shaft carries two eccentrics, which are keyed on, and fixed longitudinally by distance tubes or sleeves.

Lubrication (General).—A supply of oil is carried in a well in the engine case or crank chamber, and the oil from all bearings drains back into it. From the well a pump forces the oil into each of the bearings in succession, by the action of a Clarkson patent distributor. This arrangement ensures every bearing being properly oiled, without any further attention than occasionally, say once a week if in regular use, adding a little oil to the well.

Lubrication (Cylinder).—The cylinders are fed by a positive pump contained in an aluminium reservoir, and driven by worm

gearing from the engine. The lid of the reservoir covers a large opening, and is so arranged as to be quickly removable for inspection and refilling.

Pumps.—Four bronze force pumps, driven direct from the differential shaft, deal with boiler feeding, return water, fuel, and lubricating oil. The pumps are fitted with Clarkson patent high-speed valve boxes, and are interchangeable. Two hand pumps are also provided, one for the boiler feed, and the other for charging the oil-pressure tank. A steel air vessel is connected to the boiler feed pump to equalize delivery.

Piping.—All pressure-pipe lines are made of seamless steel, and the joints are flanged and secured by steel unions.

Tanks.—Comprise a galvanized-iron water tank of 24 gallons capacity, fitted with glass gauge, mud pocket, drain cock, filling and suction strainer, and the top made removable for inspection and cleansing. The main fuel tank, of 28 gallons capacity, made of sheet steel, riveted together and galvanized, and fitted with glass gauge, and graduated scale, filling and suction strainers, and part of the top made removable for inspection and cleansing. The pressure tank of seamless steel, fitted with pressure and Klinger gauges, and tested to 200 lbs. per square inch by hydraulic pressure.

Valves, Gauges, and Fittings.—All of the highest class and of practical construction. The gauges being placed conveniently before the driver, so as to be easily read without the assistance of a mirror.

Brakes.—There are two independent brakes acting directly upon the driving wheels, viz. a band brake worked by a foot lever, and an internal expanding brake worked by hand, and capable of locking. Both the above brakes have metallic surfaces, which grip well, but cannot fire.

Steering.—Irreversible, and operated by a wood-rimmed wheel, suitably connected to the Ackermann axle.

Feed Water Heater.—The feed water is forced through a coil heated by the exhaust steam before entering the boiler.

Oil Separator.—A cylindrical filter for the removal of the oil and graphite is fitted in the water tank, so as to be conveniently accessible. The weekly cleansing can be done easily in five minutes, and no grease is dropped on the ground.

Condensers.—Two condensers are supplied. The first

rectangular form, made of Clarkson patent tubes, fitted into aluminium side pockets, partitioned to cause the steam to traverse a long path. The second condenser, behind the first, shaped to fit round both sides of the pointed front, and with a single row of Clarkson tubes fixed in curved copper headers. One drum, forming a water pocket or "hot well," collects from both condensers, and any uncondensed vapour is permitted to escape into the flue.

Driving Chains.—These are of steel roller chain $1\frac{3}{8}$ in. pitch, having a breaking load of 5 tons.

Wheels.—34-in. diameter artillery pattern, with steel hubs and rims and cleft oak spokes.

Tyres.—"Turner" solid endless rubber tyres, 34-in. single to the front wheels, and 34-in. twin to the rear wheels.

Tools and Spares.—These comprise wrenches to fit all sizes of nuts and heads in the chassis, pliers, screw-driver, oil-can, copper wire and washers, one set spare pump valves, packing, rubber mat, rubber hose, tank gauge glasses and rubber rings for same, split pins, nuts and screws; the whole of which are fitted into a tool box conveniently arranged on the boiler.

Tests.—The chassis is loaded with an equivalent weight of 10 stone per passenger during tests, and the vehicle is run 50 miles on ordinary roads, successfully climbing a test hill of 1 in 10 during the trials.

The makers undertake to supply free of cost a new part to replace any that may fail through defective material or workmanship within six months of delivery.

It will be noticed that in both the omnibuses the drivers' seats are efficiently protected at the front and overhead, thus admitting of comparative comfort to those in charge during inclement weather. Aluminium enters largely into the construction of the bodies, and the wheels are of the artillery pattern, fitted with 3-in. solid rubber tyres. The entire driving mechanisms are carried upon the main frames of the vehicles, which frames are supported by semi-elliptic side springs located at the front and rear. Two brakes, worked by pedal levers, are fitted to each vehicle, operating directly on the hind wheels. These brakes are of the shoe type, bearing against the inner surface of rings fixed to the wheel spokes, and of the double-acting band pattern with the brake drums secured to the chain wheels, the shoe and band

brakes on each vehicle being interconnected by means of steel wire ropes, so as to equalize the pressure. The steering gears are of the Ackermann type, and operated by means of hand wheels, although in some instances the smaller omnibus is fitted with a lever, so arranged that it can be turned up out of the driver's way when not in use.

Referring to the smaller car shown in Fig. 15, the side windows are so constructed that the upper halves can, if desired, be folded down, and the two front windows can be opened so as to allow the passengers to hold communication with the driver or other persons on the front seat.

As the construction of the mechanisms in these vehicles is practically the same, the following description of the smaller omnibus will serve for both. The boiler is of the vertical fire-tube type, fitted with solid drawn steel tubes. It is located at the front of the vehicle, and the flue, which is oval in cross section, is taken up centrally through the roof, its largest diameter being placed lengthways of the vehicle so as to obstruct the view in front as little as possible. Curved glass windows are provided on each side of the flue, as shown, which windows are capable of being opened when desired. The heating is effected by a Clarkson burner, which, as has been already noticed, is capable of using several grades of ordinary paraffin oil, automatic regulation being effected by the pressure of steam in the boiler. At the rear of the vehicle underneath the frame is provided an oil reservoir, fitted with a gauge, by means of which the level of the oil can be ascertained at any time. From the oil reservoir the oil for consumption is forced by means of a small pump into a receiver placed at the front end of the vehicle, which receiver contains an air cushion serving as a storage of energy both to ensure an even and uninterrupted supply of oil to the burner when running, and also to provide means for feeding the oil thereto when the vehicle is at rest, and the engine shut down. A relief valve is provided in the oil delivery pipe, which is arranged to open when the desired pressure is obtained, returning the surplus oil to the suction side of the pump. For automatically regulating the burner, a small spring-loaded plunger, actuated by the steam pressure in the boiler, is provided. This device is so set that the supply of fuel will be cut down to the lowest point when the boiler pressure is at the normal working one, whilst the supply of fuel, on the other hand,

will be at its highest when the pressure in the boiler falls below a certain predetermined pressure per square inch. For the preliminary heating of the main burner, when starting, an auxiliary burner using the same fuel is provided beneath the front footboard. The feed water for the boiler is stored in two elongated reservoirs located under the seats in the main part of the body of the vehicle, and projecting towards the front beneath the driver's seat. These reservoirs have each a capacity of 17 gallons, and a combined capacity of 34 gallons, which, as already mentioned, is a sufficient supply of water for a run of 120 miles, and the driver can ascertain the amount of water present at any time by the inspection of a gauge glass placed on the board in front of his seat, which is termed by the makers, and not inappropriately, the "dial board."

The steam engine comprises two double-acting cylinders, and is mounted centrally under the floor of the vehicle, the cylinders projecting to the rear, and the crank chamber, which also contains the differential gear and a transverse countershaft mounted on four double ball bearings, being completely enclosed, or cased in. "Joy" valve gear is used to operate the slide valves, which latter are placed beneath the engine cylinders. A steel spur wheel placed between the two cranks transmits the power to a phosphor-bronze wheel that surrounds the differential gear. The above-mentioned countershaft drives four pumps, viz. a feed-water pump for the boiler, a pump circulating the lubricating oil for the working parts of the engine and gearing, a pump returning the water of condensation from the condenser back to the main water reservoirs, and, lastly, the pump forcing the paraffin from the oil reservoir to the pressure receiver. On each extremity of the countershaft are fixed chain wheels which are geared, through long side chains of the roller pattern, with the rear driving wheels of the vehicle. The usual swinging distance rods and means for tightening the driving chains are also provided.

Each of the cylinders of the engine has a separate exhaust pipe, these pipes passing along on each side of the vehicle, and conducting the exhaust steam through feed-water heaters to the condenser, situated in front of the bonnet, the first portion of which condenser consists of two tubes, U-shaped in plan, placed one above the other and connected by vertical tubes, in which a small portion of the steam is partially condensed, the remainder

being delivered from the apex or bend of the uppermost U-shaped tube to a large curved flat condenser box or casing, which is carried in front of the vehicle. In this latter tube the bulk of the exhaust steam is condensed, and the resultant water is delivered into a receiver situated below, into which the water of condensation from the U-shaped tubes is also delivered through a suitable pipe. From this receiver the water is drawn by the pump driven from the countershaft, and is delivered thereby to duplicate filters, and thence into the water reservoir. The greater portion of the oil carried over with the steam is removed from the water in the above-mentioned filters, and what remains is taken up in a sponge box or filter in the water reservoir, which sponge filter box is so arranged that the sponges can be readily got at when desired, and the covers of the various reservoirs are likewise so constructed as to afford ready access. The several steam pipes are of weldless steel, and the ends are spun over so as to admit of good sound face joints being made.

The speed of the vehicle is chiefly controlled by manipulating the throttle valve, which operation can be effected by means of a large mahogany-rimmed wheel which extends from the dial board in such a position as to be directly in front of the driver. On the dial board are also placed the water gauge, which has been already mentioned, and which is located close to the throttle-valve wheel, a pressure gauge mounted at or near the centre of the board, and an oil reservoir for cylinder oil having connected therewith two small force pumps, which can be operated by the driver through a projecting handle, so as to force a few drops of oil into the cylinders against the upper parts of the pistons (about every five miles being found to be sufficient when running), and, owing to the slide valves being placed beneath the cylinders, this oil also serves to lubricate the former. Owing to the slide valves being placed in this position, moreover, any water that may result from the condensation of steam in the cylinders when the engine is shut down readily drains out of same into the exhaust pipe on again starting.

For operating the reversing gear and admitting of the driver varying the cut-off of the slide valve with relation to its travel in a forward direction, a lever is provided at the right-hand side of the driver, in connection with which is a quadrant having several "ahead" notches, a neutral notch, and a reversing notch.

For feeding the boiler and supplying the burner with fuel when the vehicle is at rest and the engine shut down, and for obtaining the necessary pressure in the pressure receiver when first starting, two hand pumps are provided, either of which can be operated by a lever extending up vertically through the floor on the left-hand side behind the dial board.

The details of construction of the driving mechanism are shown in Figs. 17 to 28. In Figs. 17 and 18 *a* indicates the rectangular

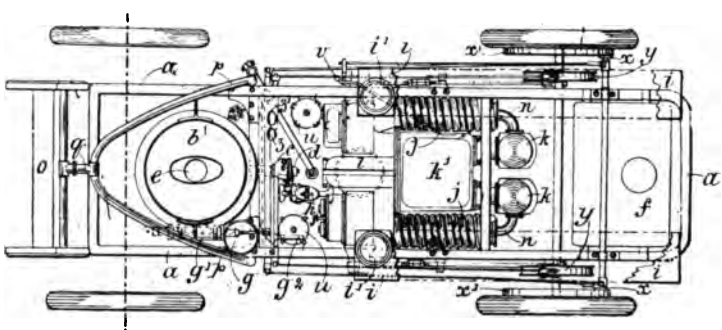

Fig. 17.—Clarkson steam omnibus. Plan of frame and driving mechanism.

main framing made of channel steel; *b* is the multi-tubular boiler or steam generator, which is secured as shown to the front part of the rectangular frame *a; c* is the liquid fuel burner, which is mounted directly under the boiler *b; d* is the lamp for the initial heating of the vaporizing coil of the burner, which lamp can be readily got at under the floor of the driver's seat; *e* is the oval boiler flue projecting vertically from the bonnet; *f* is the main oil reservoir located at the rear of the frame *a; g* is the pressure receiver into which the oil is pumped from the main oil reservoir *f*, either by the mechanically operated pump or by the hand pump g^1 worked by the lever g^2, which also works the auxiliary boiler feed pump, and which pressure receiver is placed at the rear of the boiler *b*. The pressure receiver *g* is strongly made, and so constructed that there will be a lodgment or cushion of air in the top of the chamber, the oil being forced into it from the bottom, and the compressed air in this space providing a sufficient store of energy to feed the requisite supply of oil to the burner when

the vehicle is at rest and the engine shut down, as well as forming, as already mentioned, a cushion, and tending to equalize the pressure when running. Means are likewise provided for renewing the supply of air, and two try-cocks, by means of which the driver can ascertain the level of the oil when desired, project from the dial board with a cup for catching any oil discharged therefrom, and delivering same by means of a pipe to the preliminary heating lamp *d*. From the pressure receiver *g* the oil passes directly to the liquid fuel burner *c*, through a stop-cock, mounted on

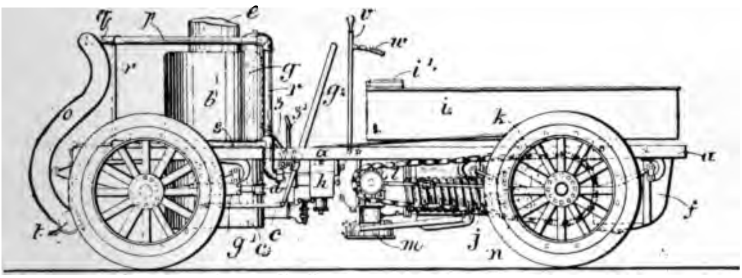

Fig. 18.—Clarkson steam omnibus. Side elevation of frame and driving mechanism.

the dial board directly in front of the driver. *h* is an automatic regulating device which operates to lower the flame when the steam pressure in the boiler *b* rises to a certain predetermined point, and to raise the flame to its maximum strength when the pressure again becomes lowered.

The water for feeding the boiler *b* is stored in the two connected water reservoirs *i*, which are mounted upon each side of the frame *a*, and lengthways thereof, so that in the finished vehicle they are situated beneath the seats at each side of the body, and the ends project underneath the driver's seat in front. Large-sized covers, i^1, are provided so as to admit of easy access being had to the interior of the reservoirs for cleansing and other purposes, and a funnel-shaped filler fitted with a wire gauze strainer enables the filling of the reservoirs to be effected. The feed water from the water reservoirs *i* is passed through two feed-water heaters, *j*, before being delivered into the boiler *b*.

k is the horizontal two-cylinder double-acting high-pressure engine, which is secured underneath the frame *a*. The cylinders

are bolted to box castings, enclosing the stuffing boxes and glands, which box castings are in turn secured to an enclosed crank box or chamber, k^1, which latter, as well as the crank shaft bearings, are bolted to a casing, *l*, enclosing the differential gearing and the transverse countershaft, mentioned in the short preliminary general description, and on which countershaft are four eccentrics for working the feed water, lubricating oil circulating, condensed water, and liquid fuel, pumps. *m* is a small oil receiver which is fixed below the casing *l*, and into which passes the lubricating oil from the bearings.

n are the exhaust pipes which deliver the exhaust steam from the engine *k* to the feed-water heaters *j*, which latter are externally wound with spiral coils of wire to help by air cooling in the reduction of the temperature of the exhaust steam before its delivery into the flat curved condenser *o*, through the U-shaped pipe *p*, and connecting pipe *q*, which pipe *p* forms practically the top of the condenser, assisting to a certain extent in the condensation of the exhaust steam, and being connected by the vertical wire-covered pipes *r*, with a similar shaped pipe, *s*, situated below. The greater portion of the exhaust steam passes along the upper U-shaped pipe *p*, which is the direct course to the curved portion *o* of the condenser, but a certain amount thereof also descends the vertical wire-covered tubes *r* to the pipe *s*, and is condensed therein. The curved portion *o* of the condenser is fitted with a number of transverse tubes, and the water resulting from condensation in this portion of the condenser, as well as that from the U-shaped portions thereof and vertical tubes, is delivered by gravity into a collecting drum, *t*, located at the bottom of the condenser, any of the exhaust steam remaining uncondensed being passed into the boiler flue and escaping therefrom into the atmosphere, as invisible vapour. From the collecting drum *t* the water of condensation is passed through the filters *u*, and the sponge filter box by which any oil carried over from the cylinders is removed, into the water reservoir *i* situated on the right-hand side. This sponge filter box consists of an open-ended cylinder, arranged vertically inside a second and larger cylinder closed at the lower end, but provided with perforations near its upper and open extremity.

v is the reversing lever which is connected with the valve gear through a set of levers and a rocking shaft mounted transversely

below the engine crank box or chamber, so that when rocked on its pivots it will operate to move the reversing gear in the one or the other direction. On the reversing lever *v* is provided a notched quadrant, *w*, and a catch or detent—not shown in the drawing, but which is pivoted to the body of the vehicle—is arranged to engage with any one of these notches so as to hold the lever firmly in any desired position. This arrangement allows

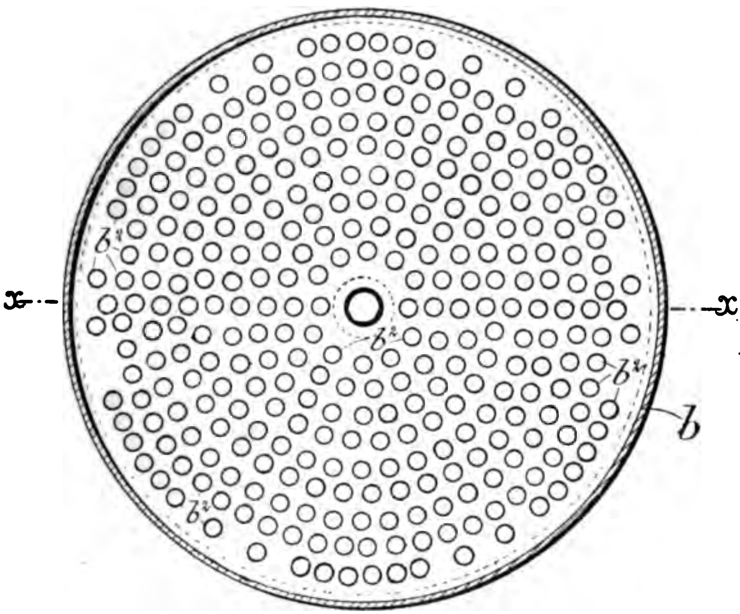

Fig. 19.—Clarkson steam omnibus. Horizontal section of multitubular boiler.

the driver to vary the cut-off of the engine when running in a forward direction, and to reverse the direction of motion.

x are the shoe brakes, and *y* are the band brakes, the former being connected with the operating pedal *z*, and the latter with the pedal z^1, both of which project from the floor in convenient positions in front of the seat of the driver. As before mentioned, the shoe brakes bear against the inner faces of rings, *x*, fixed to the rear wheels, whilst the band brakes work on drums secured

to the chain wheels, and each pair of brakes is so constructed, moreover, that there will be a compensating action on each wheel.

The arrangement of brakes is such that they will operate just the same were either of the driving chains to break or come off, and, in addition to these brakes, the engine itself can be used as a brake by closing the throttle valve and reversing the lever, so as

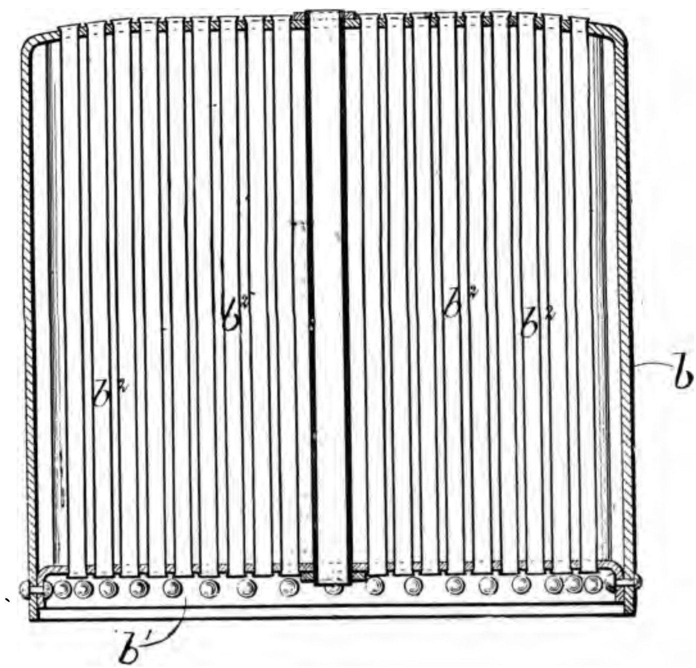

Fig. 20.—Clarkson steam omnibus. Vertical central section of multitubular boiler.

to cause it to act as a pump, and thus to arrest the motion of the vehicle. The steering wheel is mounted on a vertical shaft journalled to rotate in a suitable sleeve or bracket, and connected in the well-known manner to the heads of the front or steering wheels.

The construction of the boiler *b* is shown in Figs. 19 and 20, drawn to an enlarged scale. The shell is cylindrical, and, as will be seen from Fig. 20, is formed in one piece with the top plate,

the circular bottom plate b^1 being flanged and riveted to the shell. The tubes b^2, which are of small diameter, and of which there are a large number, are expanded into the upper and lower plates of the boiler. The shell and bottom plate b, b^1 are of steel, and the tubes b^2 are weldless steel. The boiler is fitted with twin safety valves, and has also all the other fittings generally provided.

The construction of the engine k and differential gearing is shown in Figs. 21, 22, and 23, which views are also drawn to an enlarged scale. As will be seen from Fig. 21, the cylinders k are

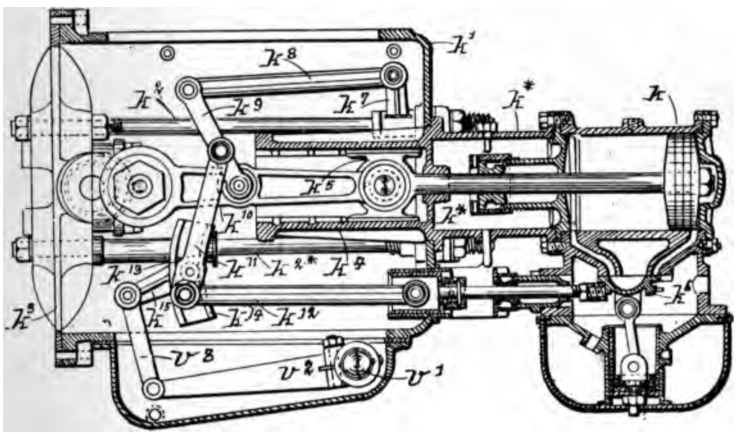

Fig. 21.—Clarkson steam omnibus. Vertical longitudinal central section through one of the cylinder and crank chambers of engine.

secured to intermediate castings, k^*, which latter are, in turn, connected with the crank chamber k^1 by means of the long bolts k^2, k^{2*}, which pass through the crank chamber k^1 and the cover k^3 of the latter. The intermediate castings k^* form chambers enclosing the stuffing boxes and glands of the piston rods, and extensions, k^4, formed integral with the castings k^*, project into the crank chamber k^1 and serve as guides for the crossheads k^5. The slide valves k^6 are, as has been already mentioned, operated by valve gearing of the Joy radial type. k^7 are brackets secured to the upper bolts k^2, and to which are fulcrumed the swinging levers k^8, coupled at their other extremities to the links k^9, which latter are pivoted at their other, or lower, ends to the

piston connecting rods k^{10}. k^{11} are double links, pivoted, as shown, to the links k^9, and coupled at their lower extremities to the slide valve connecting rods k^{12}. k^{13} are blocks mounted to slide freely between guides, k^{14}, pivotally supported by means of hollow trunnions journalled in suitable bearings secured to the lower bolts k^{2*}.

The slide blocks are connected near their lower ends with the double links k^{11} through pins on the latter, which fit into holes provided in the former, and by which means it will be seen

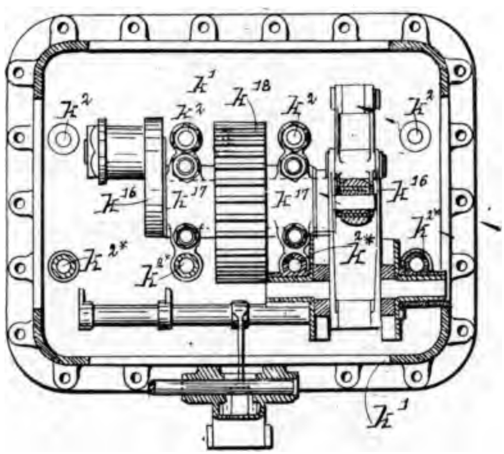

Fig. 22.—Clarkson steam omnibus. Transverse section of crank chamber, showing crank shaft and valve gear.

that whilst the slide valve connecting rods k^{12} are operated by the piston connecting rods (k^{10}) at the same time, the manner in which this is effected, and, consequently, the direction in which the engine rotates, is governed by the position to which the guides k^{14} are adjusted on their pivots by the rocking shaft v^1, which is located beneath the crank chamber k^1, and is connected with arms or projections, k^{15}, on the guides k^{14}, through the crank arms or levers v^2, and links v^3, the rocking shaft v^1 being, as has been already mentioned, coupled through an arrangement of levers and connecting rods with the reversing lever v (see Figs. 17 and 18), located at the right-hand side of the vehicle. In this manner the throw of the slide valve can

be altered, and the direction of motion of the engine can be reversed, and the amount of cut-off can likewise be varied by operating the reversing lever *v*, and locking it in the desired position by means of the notched quadrant *w*, and catch or detent on the side of the vehicle.

The crank shaft is formed with two overhanging cranks, k^{16}, set at an angle of 90° to each other, and supported in bearings, k^{17}, provided in the casing k^1. k^{18} is a steel toothed driving wheel, which is fixed centrally upon the crank shaft, and which gears or meshes with a phosphor bronze toothed ring, l^1, of double the diameter, surrounding the differential gearing l^2, which is enclosed in a casing, *l*, formed in two parts, divided centrally and vertically. As will be seen from Fig. 23, the differential gearing l^2 and its countershaft l^3 is enclosed in the casing *l*, and the former consists of a train of toothed wheels, the large phosphor bronze toothed ring l^1, by which it is driven from the steel toothed driving wheel k^{18} on the engine crankshaft, being bolted in the manner shown between the two parts of the casing l^4 surrounding the train of toothed wheels l^2. The casing *l* is provided with four double ball bearings, l^5, fitted with $\frac{1}{2}$-inch balls, supporting the countershaft l^3, and the casing *l* is secured by bolts at each extremity to the main frame *a* of the vehicle, one end of each of the side driving-chain tightening rods being likewise secured to the casing *a* as shown at l^6.

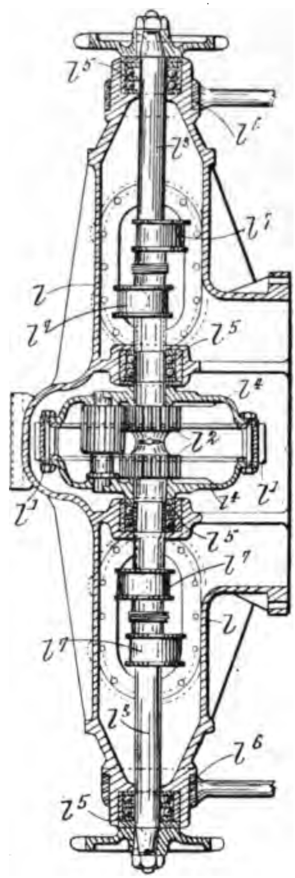

Fig. 23.—Clarkson steam omnibus. Horizontal longitudinal section showing differential gear and countershaft.

l^7 are eccentric blocks fixed on the two halves of the counter-

shaft l^3, which blocks serve to operate the four feed pumps, two of which are located at each side of the vehicle, and the chain wheels are mounted on the outer ends of the countershaft, motion being communicated therefrom to the rear wheel axle by roller chains meshing with chain wheels on this axle, in the usual manner. The feed pumps driven by the eccentrics on the countershaft l^3 are mounted vertically beneath it on the casing l.

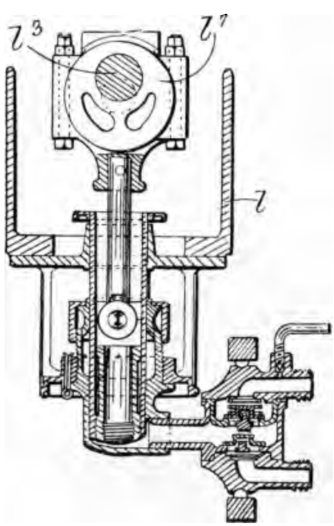

Fig. 24.—Clarkson steam omnibus. Vertical central section of mechanically driven force pump.

These four pumps, the construction of which is clearly shown in the sectional view, Fig. 24, serve, one for feeding the boiler with water from the main reservoirs *i*, (Figs. 17 and 18), the second for returning the water resulting from the condensation of the steam from the drum or hot well *t* to the main reservoirs *i*; the third for pumping the liquid fuel from the main liquid fuel reservoir *f* to the pressure receiver *g*; and the fourth for forcing the lubricating oil from the reservoir *m* located beneath the differential gear to the various moving parts of the engine and countershaft, from which it again passes into the above-mentioned reservoir. The first two of these pumps have strokes of one inch, whilst the two latter have half-inch strokes; otherwise they are identical in construction.

There are also provided, as already mentioned, two other pumps adapted to be operated by hand, one of which is intended for forcing liquid fuel from the main reservoir *f* into the pressure receiver *g*, and the other for supplying feed water to the boiler when the engine is shut down. These pumps are shown at g^1 (Figs. 17 and 18), and are operated by a hand lever, g^2, which projects from the floor on the left-hand side of the vehicle, and is connected by a series of levers, as more clearly

shown in Fig. 18, with the common piston rod, the two pumps being arranged in line and facing each other.

Fig. 25 shows the general construction of the Clarkson burner. The supply of air is regulated in this burner by altering the amount of the opening of a rotary perforated disc, c^1, mounted in connection with a fixed disc provided with air inlet holes or apertures, the whole of this device being practically identical in construction with an ordinary form of hit-and-miss ventilator. The air admitted through the disc c^1 mixes thoroughly in the

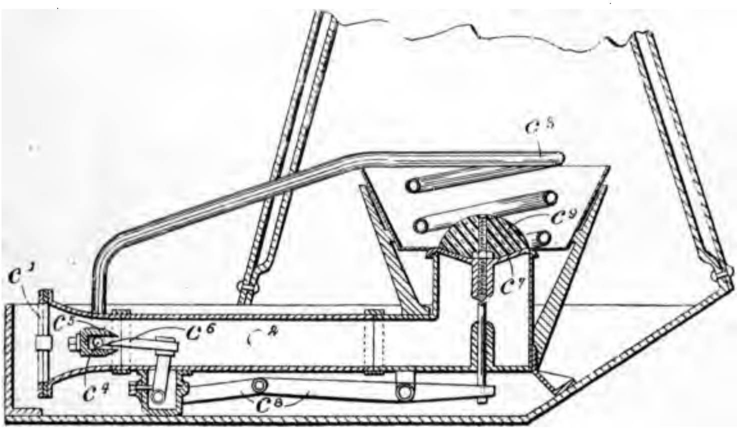

Fig. 25.—Clarkson steam omnibus. Vertical longitudinal section of burner.

mixing chamber c^2, with the oil vaporized in the coil c^3, round which the flame from the burner circulates, the vapour entering the mixing chamber c^2 through an aperture, c^4, in the nozzle c^5, which aperture is governed by a small needle valve, c^6. This needle valve, c^6, is so connected with the lid or cap c, forming a larger valve at the burner, through a suitable system of levers, c^8, that the outflow of the combined mixture of oil and air will be correspondingly regulated by the automatic oil or fuel regulating device h, shown in Figs. 26 to 28. The top of the lid or cap c^7 is fitted with a head, c^9, of refractory material, and the flame from the burner is baffled on the inside of a hollow cone constructed of nickel. The vaporizing coil c^3 is made from steel tubing, and is wound round with nickel wire in order to prevent, as far as possible, the oxidization of the steel.

The lamp *d* (Figs. 17 and 18), for starting the burner by effecting the necessary amount of preliminary heating, consists of a casting containing a wick made of asbestos, and it is so arranged that the flame therefrom will impinge upon one end of the vaporizing coil c^3. The requisite charge of oil, measured in the manner previously described, is absorbed by the wick, and the lighting can be effected without trouble by dropping a lighted match through a small aperture at the top in the floor of the vehicle under the driver's seat, which aperture is normally closed by a suitable door or cover. The burning of the lamp *d* is then accelerated by a forced draught produced by means of a fan driven by clockwork mechanism, which concentrates a blow-pipe flame upon the vaporizing coil c^3. The clockwork fan is located beside the starting lamp *d* underneath the floor, and the fan runs for a sufficient length of time to effect the heating of the vaporizer. The winding up of the clockwork mechanism for driving the fan only occupies a few seconds.

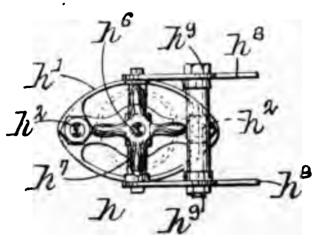

Fig. 26.—Clarkson steam omnibus. Plan view of automatic burner regulating device.

Figs. 26, 27, and 28, drawn to a greatly enlarged scale, show clearly the construction of the device *h* for automatically regulating the supply of oil to the burner. This automatic oil regulator comprises two heads, h^1, secured to each other by two long bolts h^2, and the lowermost head having a cylindrical extension, h^3, in which is adapted to work a plunger, h^4. This plunger, h^4, is acted upon by a taper piece, h^5, having a rod or stem, h^6, passing through a hole provided in the upper head h^1, and its free end is secured by means of a four-armed nut, and locking nuts, as shown, to a cross piece, h^7, connected to the short arms of bell-crank, levers h^8, fulcrumed at h^9 to the top head h^1. The plunger h^4 is retained in its normal position at the bottom of the cylinder by means of the powerful helical spring h^{10}, the exact relation of its position with regard to the bottom of the cylinder h^3 and the bell-crank levers h^8 being regulable by means of the above-mentioned nuts. The long arms of the bell-crank levers h^8 are connected to the device

which operates to regulate the supply of oil and air to the burner.

To the bottom inlet h^{11} in the cylinder h^3 is connected a steam pipe from the boiler *b*, and as the steam pressure in the latter rises it will force the plunger h^4 upwards against the helical spring h^{10}, compressing the latter, and through its rod or stem, h^5, acting on the bell-crank levers h^8 to move them about the fulcrum h^9 and to operate the closing of the device, so as to cut

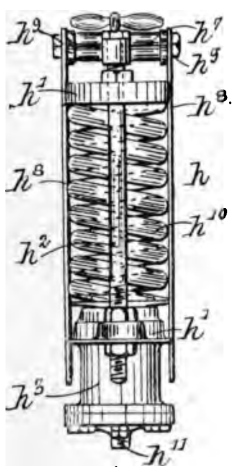

Fig. 27. — Clarkson steam omnibus. Elevation of automatic burner regulating device.

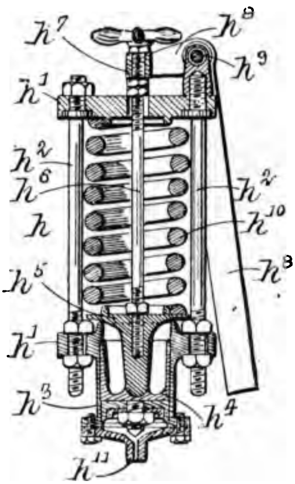

Fig. 28. — Clarkson steam omnibus. Vertical central section of automatic burner regulating device.

off the supply of fuel and air from the burner *c*. On the other hand, a reduction of the steam pressure in the boiler *b* will allow the helical spring h^{10} to reassert itself, and to force the plunger h^4 back to its normal position in the cylinder h^3, turning the bell-crank levers h^8 in the reverse direction about the fulcrum h^9, and again opening the device so as to allow the full supply of oil to pass to the burner *c*. The pressure found to be most suitable for the fuel feed is one of about 40 lbs. per square inch, and this comparatively high degree of pressure, combined with the special arrangements used for throttling, prevent any surging

from taking place, and ensure the production of an even flame. Important features in the liquid fuel apparatus are the means for regulating the amount of heat generated by the main burner, by varying, in the same proportion, and also, at precisely the same time, the quantities both of the oil and the air that are admitted to the burner. In the above-described manner the heat generated by the burner can be regulated through a very considerable range, the lowest being calculated to be sufficient to maintain the steam at working pressure. An advantage of this arrangement is that the safety valve does not blow off when the vehicle is at rest, except on rare occasions when, owing to very rapid steaming, the boiler, etc., have become raised to a very high temperature, and although when the vehicle is kept at rest the automatic regulating device will come into operation, there is no fear of the flame being extinguished by its action. The draught is natural, no arrangements for forcing being provided or required, and both the uptake and the chimney provide a practically vertical path for the escape of the waste products of combustion into the atmosphere.

The time occupied in getting up steam from cold water is about 12 minutes, and in order to ensure a supply of dry steam, which is especially desirable in the case of a mechanically propelled vehicle, the steam from the boiler is passed through an M-shaped superheater of the gridiron type, located just above the liquid fuel burner *c*, before reaching the throttle valve of the engine. Under normal conditions the power and speed of the engine can be satisfactorily regulated by adjustments of the throttle valve, the cut-off being set at about one-half stroke. When mounting unusually steep gradients, however, the cut-off should be varied, which can be done in a forward direction to anything between nothing and three-quarter stroke.

The thermostatic device employed for automatically regulating the supply of feed-water to the boiler is dependent for its operation on the difference in temperature between the feed-water and the steam in the boiler. The construction of the apparatus is such that when the water-level in the boiler rises above a predetermined point the device becomes surrounded with water instead of steam, as is normally the case when the device is operating to permit the feed-water to pass into the boiler, and owing to the fall in temperature thus produced, the apparatus

operates to open a bye-pass between the delivery and suction pipes of the feed pump, so that the water, or the greater part of it, circulates back to the pump instead of passing into the boiler. When, on the contrary, the water level in the boiler falls below a certain predetermined level the device again becomes surrounded with steam, and, owing to the temperature rising in consequence, the apparatus operates to close the above-mentioned bye-pass and allow the feed-pump to operate in the usual manner to feed the boiler.

Thornycroft Steam Omnibuses

The Thornycroft Steam Waggon Co., Ltd., of Chiswick and Basingstoke, which is an off-shoot of the well-known Chiswick firm of torpedo-boat builders, are makers of several different types of

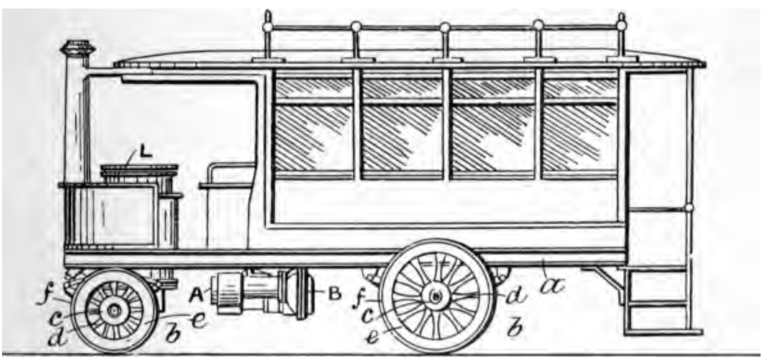

Fig. 29.—Thornycroft 14-seated steam omnibus.

steam omnibuses, and they have already established a high reputation both for these as well as for their heavy freight vehicles.

Fig. 29 is a diagrammatical view illustrating in side elevation a steam omnibus adapted to accommodate fourteen passengers inside, besides the driver in front, and about 10 cwts. of luggage on the roof. The speed of this vehicle is from 10 to 12 miles an hour.

The firm also build a double-decked type of omnibus to carry 12 passengers inside and 24 outside, with a speed of 7 or 8 miles an hour, and closed and open steam omnibuses, char-a-banc

type, and mounted on bogie carriages, each adapted to carry 30 passengers, the general appearance and arrangement of both of which latter vehicles are shown respectively in Figs. 30 and 31.

Steam omnibuses have been supplied by the Thornycroft

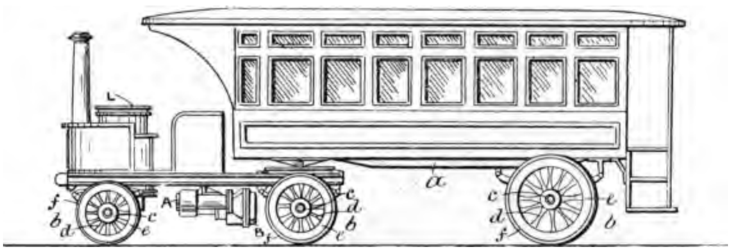

Fig. 30.—Thornycroft 30-seated steam omnibus, closed char-a-banc type.

Steam Waggon Co., Ltd., amongst a number of customers, to the Belfast and Northern Counties Railway, and, in spite of the bad condition of the roads in the district where they are in use, are said to give great satisfaction.

The following is a general description of the Thornycroft

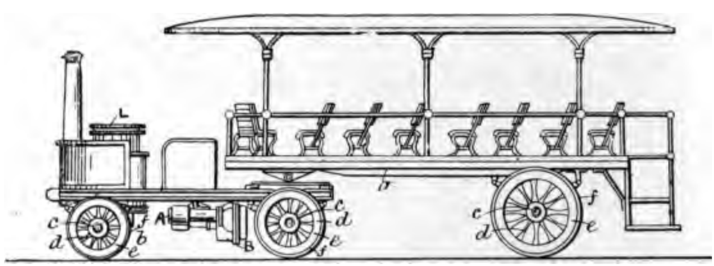

Fig. 31.—Thornycroft 30-seated steam omnibus, open char-a-banc type.

steam omnibuses (Figs. 32 to 36 showing the principal details of construction). The framework *a* is of the best channel section steel, and is strongly tied and braced. The wheels *b*, the details of construction of which are shown in Figs. 32 and 33, are of the artillery type, with metal naves (*c*), oak spokes (*d*), ash felloes (*e*), and steel tyres (*f*), the latter being pressed on by hydraulic machinery so as to avoid the charring of the felloes, that would

otherwise inevitably result from the process of shrinking on of tyres of such size and thickness as have to be employed on these wheels.

The engine (A, Fig. 34) is of the two-cylinder compound type, cylinders 4 ins. and 7 ins. diameter by 5 ins. stroke, the cylinders and valve chambers being made of two iron castings. It has a constant lead, radial valve gear whereby any degree of linking up can be obtained, and single eccentric reversing gear, both of

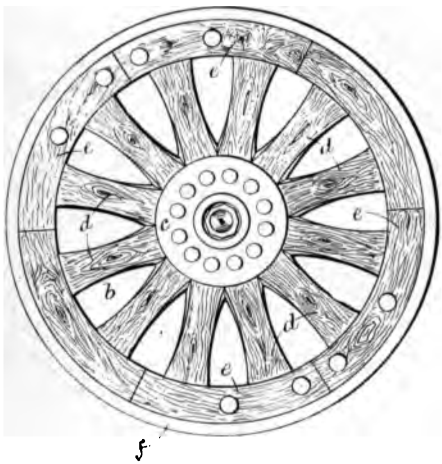

Fig. 32.—Thornycroft steam omnibus. Side elevation of wheel.

special design. The whole is enclosed, the crank shaft and valve gear in a dust-proof and oil-tight box or casing (B), and the crossheads in cast-iron sleeves, bolted to the cylinders and crank box or casing respectively, which latter, being partially filled with oil, provides for the efficient lubrication of the working parts by the splash method. The crank box or casing is provided with an easily removable door to facilitate examination and adjustment of the parts when necessary. At normal speed the engine gives about 25 brake horse-power.

The transmission gearing is of the chainless pattern. The one or other of two pinions, C, D, fixed on the engine crank-shaft mesh with corresponding toothed wheels, E, F, mounted on the first motion countershaft G. This countershaft, G, is constructed in three separate parts, the central portion thereof being

connected with the first and third portions by enclosed types of universal couplings. By means of this arrangement the vertical motion of the bearing springs of the vehicle is taken up, and a constant driving effort is transmitted to the wheels without regard to the road surface, or to the amount of load, a free motion of 7 ins. being permitted between the waggon frame and the driving axle without in the least disturbing the steady continuity of turning effort, and without any possibility of jump in the gearing. On one portion of the countershaft G are mounted the two change-speed gears, E and F above mentioned, and the other portion carries a double helical cast-steel pinion, H, which meshes with a helical steel-toothed wheel on the differential gear J, which is mounted on the rear axle K. The ends of the countershaft G carrying the double helical pinion H are supported by two triangular-shaped brackets, mounted on the rear axle K, and a radius rod jointed to the under frame of the omnibus, so as to admit of the bearing

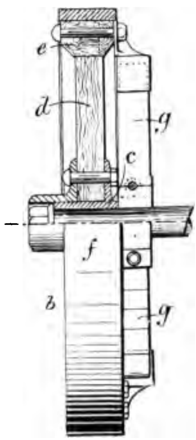

Fig. 33.—Thornycroft steam omnibus. Part vertical section of wheel.

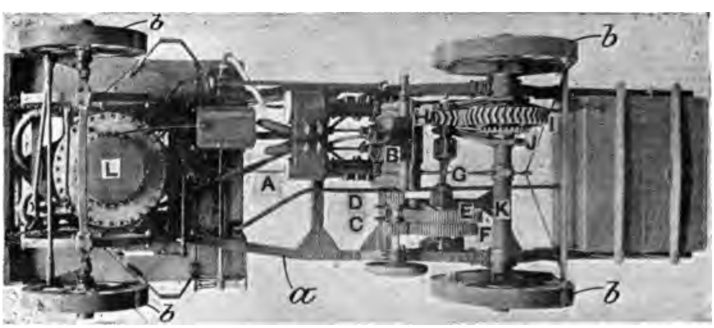

Fig. 34.—Thornycroft steam omnibus. Underside view of transmission gear.

springs of the vehicle having their full amount of play, is provided, in order to prevent the brackets from rotating round the axle.

The rear wheels of the vehicle are driven through the plate springs *g*, which are secured to the felloes, as shown in Fig. 33, thus removing the strain of the driving effort from the spokes.

The boiler L for generating the necessary supply of steam, is of the well-known Thornycroft central-fired water-tube type, in which either coal or coke is used as fuel. This boiler is shown in Figs. 35 and 36, drawn to an enlarged scale, and consists of two annular-shaped chambers or casings, a^1 and b^1, connected by a series of straight steel tubes, c^1, usually numbering 168, and $\frac{7}{8}$ in.

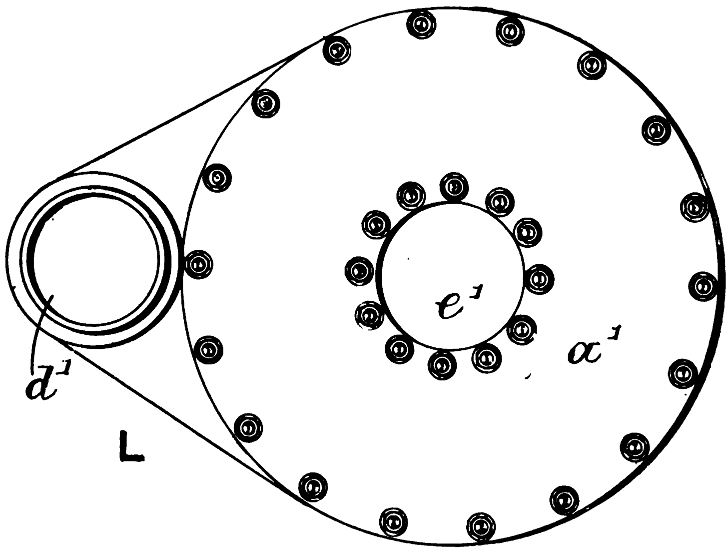

Fig. 35.—Thornycroft steam omnibus. Plan view of boiler.

diameter, arranged at a slight angle so as to form a tapered hollow cone. The uppermost chamber or casing, a^1, comprises two separate rings formed of $\frac{5}{16}$-in. steel, as shown in Fig. 36, which are riveted to an annular steel channel-shaped piece, $\frac{1}{2}$ in. in thickness. The lower chamber or casing b^1 is built up of three pieces; that is to say, of one tube plate $\frac{5}{8}$ in. thick, and two rings $\frac{5}{16}$ in. thick. The covers of both the chambers or casings a^1 and b^1 are of steel, and that of the uppermost chamber a^1 is secured in position by bolts, whilst that of the lowermost one b^1 is secured by studs. d^1 is the uptake or funnel; e^1 is an

aperture in the upper annular casing for the introduction of fuel into the furnace or combustion chamber f^1, and g^1 is the ashpan or ashpit. The connecting tubes c^1 between the two chambers a^1 and b^1 are 35 inches in length, and they have a mean inclination of $\frac{1}{16}$ in. to a foot.

The boiler is tested up to 350 lbs. per square inch, and is intended to work at a pressure of 200 lbs. per square inch. The smaller size of boiler has a heating surface of 77 sq. ft., and a grate area of 2·4 sq. ft., the total weight being 13·75 cwts.

The steering of the omnibus is on the Ackermann principle, as shown in Fig. 34, a hand wheel operating through worm gearing being provided for turning the front wheels.

The Liquid Fuel Engineering Company Steam Omnibuses

The above firm, whose works are at East Cowes, Isle of Wight, build both large and small omnibuses, which, as well as their heavy vehicles, are known by the peculiar name of "Lifu" vehicles. The frames of the vehicles are made of light channel steel, and the front and rear axles are connected by tubular stay rods. The engine is secured centrally to the frame, which also carries the transmission gear, enclosed in an oil-tight casing, motion being transmitted by means of a spindle located in a tube on a sleeve carrying a bevil pinion at its extremity, which pinion also runs in an oil-tight casing, and drives a countershaft, the pinion gearing, with another pinion, forming part of the differential gear. The latter drives a spindle in two parts, each part of which carries at its outer end a toothed wheel or pinion, the teeth of which are angled to correspond with those of internally toothed rings secured to the spokes of the dished driving wheels by means of clip bolts. The vertical movement of the differential gear spindle is provided for by means of an arrangement of sliding or telescopic transmission shaft.

The engine is of the compound horizontal reversing link type, the cylinders being respectively of 3 ins. and 6 ins. in diameter, by 5 ins. stroke. The glands are situated within distance pieces or castings between the cylinders and the guide bars, and in addition to the usual stuffing boxes and glands on the cylinders to prevent the escape of steam, there are also others at the end of

the above-mentioned castings to prevent any water due to condensed steam from gaining access to the crank box or casing. The

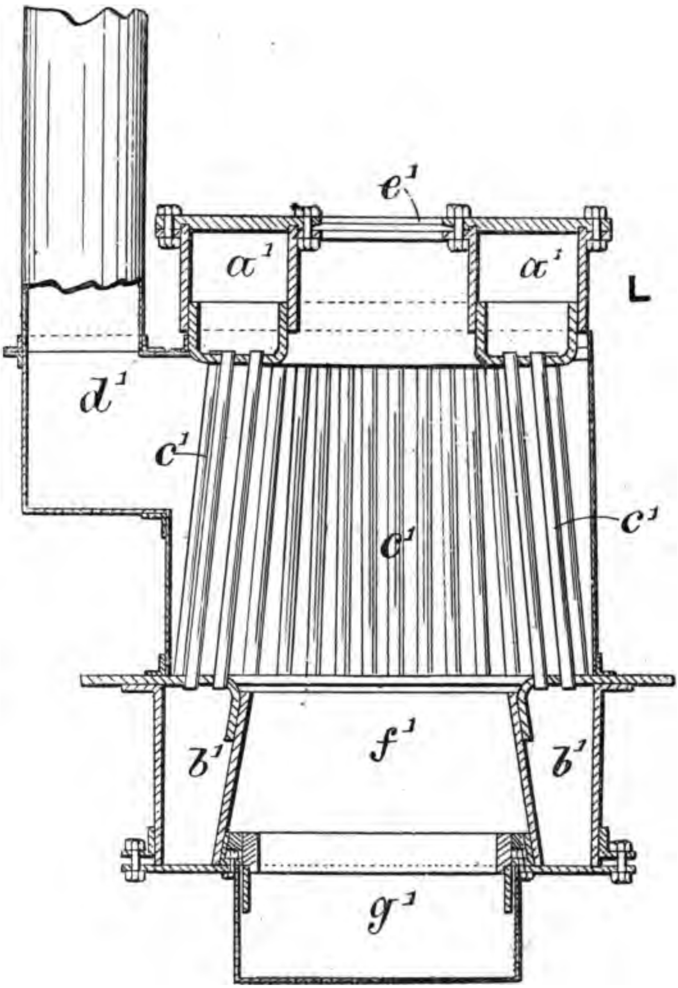

Fig. 36.—Thornycroft steam omnibus. Vertical central section of boiler.

valves are of the piston type, and are operated by dog links. There are two boiler-feed pumps, one of which is driven by an

eccentric on the external extremity of a spindle driven by gear wheels, and a forked connecting rod, secured to a crosshead behind the pump; and the other being an independent steam pump located below the footplate, for use when the engine is at rest. Between the cylinders is a receiver, at the high-pressure end of which is a connection for admitting live steam from the boiler to the low-pressure cylinder when necessary.

The boiler is located centrally at the front of the vehicle, and is of the water-tube type, the extremities of the tubes being connected to a central drum or cylindrical vessel, and to a circular trunk tube, by gun-metal unions. On the top of the central drum or cylindrical vessel is a small steam dome, which increases the steam space in the former. The drum or cylindrical vessel is formed of copper, and its external diameter is 14½ ins., the length being 30 ins. It is secured to a hollow bridge on the lower circular trunk tube by a screwed joint, the trunk tube and bridge being of gun metal and formed in one piece. The water tubes connecting the central drum and the lower trunk tube are ½ in. internal diameter. A flange or rib is cast round the trunk ring or tube, upon which is supported a light iron casing lined with asbestos sheeting. In order to provide for access to the burner for lighting and cleaning purposes, a portion of the trunk ring or tube can be raised. Below the boiler is an armed casting, which carries the burner and coned and annular partly coned plates. The water tubes rise vertically from the lower circular trunk for some nine inches, after which they are given spiral bends in alternate directions to the central drum. The water gauge is mounted on a trunk pipe to the upper part of which is connected the steam pressure gauge. The feed-water pipe has two check valves, which are readily accessible.

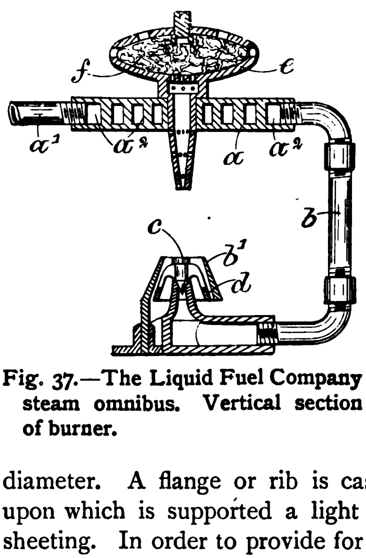

Fig. 37.—The Liquid Fuel Company steam omnibus. Vertical section of burner.

The burner and vaporizer is shown in Figs. 37 and 38 in

vertical and horizontal sections, the vaporizer being of cast iron, and the construction readily understandable from the drawings. Oil entering the vaporizer *a* through the oil inlet a^1 is forced to take a circuitous path backwards and forwards and then downwards through the passages a^2 and pipe *b* to the burner b^1, the pressure in the oil tank being sufficient to cause the central valve *c* and its pointed spindle to rise when only a small flame is required. When, however, a more powerful flame is necessary, an increased pressure is applied, in which case not only the above valve, but also the larger one *d* at the bottom of the burner is raised, and a large and powerful flame is produced, which impinges against and envelops the flat cheese-shaped vaporizer, maintaining both this and the igniter *e* at a high temperature, and completely filling the interior of the fire-box.

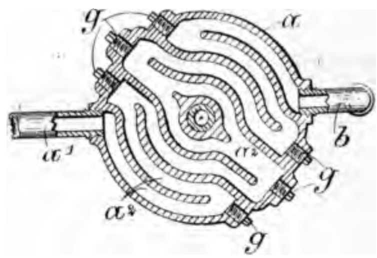

Fig. 38.—The Liquid Fuel Company steam omnibus. Horizontal section of burner.

The igniter *e* is a hollow casting somewhat of the shape of a top, the hollow stem or peg of which fits into a central hole in the vaporizer *a*, and the interior space or chamber within which is partly filled with refractory material, *f*. The use of the igniter *e* is to store up sufficient heat to re-ignite the vapour from the burner, should a strong gust of wind from the exterior, or the compressed air in the oil supply tank being released suddenly, blow out the flame. *g* are screw plugs which can be removed to afford access to the passages a^2 for cleansing purposes. A small air pump, driven from the head of the feed-pump plunger, and having an air inlet protected by fine gauze wire, supplies air at a pressure of about 15 lbs. per sq. in. to the oil tanks, and this pressure forces the oil through a filter to the vaporizer. The supply of oil is regulated by a steam diaphragm which is in connection with the steam pressure in the boiler.

The exhaust steam from the low-pressure cylinder is passed through a feed-water heater, after leaving which heater it is conducted into a silencer before passing into the uptake and thence escaping into the atmosphere. The water resulting from

condensation of the exhaust steam in the feed-water heater and silencer is delivered into the feed-water tank, which is located on the right-hand side of the boiler. The crank box or casing is formed of bronze, except the front portion and that covering the pump, which is of aluminium. The steering is of the Ackermann type.

De Dion and Bouton Steam Omnibuses

Steam omnibuses built by Messrs. de Dion and Bouton have given very satisfactory results in France. As a typical example of their system may be taken the steam omnibus that was run by this firm in the 1897 trials organized by the Automobile Club of France. This vehicle weighs, without passengers, 4 tons 10 cwts., and when fully loaded over two-thirds of the weight is carried upon the rear wheels. The total length is 21 feet, 6·5 feet being taken up by the space occupied by the boiler, coke box, and driver's seat, 10·75 feet being devoted to the accommodation of passengers, in the body of the vehicle, and 3·75 feet being devoted to a rear covered platform. The breadth of the vehicle is 6·50 feet. The omnibus seats sixteen passengers, twelve in the main body and four on the rear platform.

The engine, which weighs, with the gearing and casing, 15·8 cwts., and develops 24·5 horse-power when running at a speed of 600 revolutions per minute, is mounted beneath the underframe of the vehicle. It is of the horizontal compound type, the cranks being at angles of 90 degrees, and the high and low pressure cylinders 3·95 ins. in diameter and 7·5 ins. in diameter respectively, by 6·7 ins. stroke in both cases. The cut-off in each of the cylinders is at three-quarters of the stroke, and, by means of a specially designed valve, the full steam pressure can be admitted when desired to both cylinders. The cranks are of the disc pattern, and are keyed on the extremities of the crank shaft, which latter also carries two toothed pinions of different diameters, either of which can be brought into gear with correspondingly toothed wheels on a countershaft, thereby varying the speed of the vehicle from 8·7 to 12·4 miles per hour. The slide valves, which are situated above the cylinders, are operated by eccentrics, the sheaves of which are mounted on a shaft geared to the crank shaft through a suitable train of toothed wheels. The engine can

be reversed by effecting an alteration in the number of toothed wheels in this train by means of a hand lever, which operates through a link connected to one arm of a bell-crank lever, to bring into gear an idle toothed pinion, mounted on a small spindle or stud fixed in a double lever pivotally mounted to the frame. The counter-shaft, driven by one or other of the toothed pinions on the crank shaft, has fixed on it another toothed pinion, which meshes with the driving wheel of the differential gear, and the rear wheels of the vehicle are driven by the De Dion patent system of transmitting power. This system consists briefly of coupling boxes on the differential gear shaft, in which boxes are

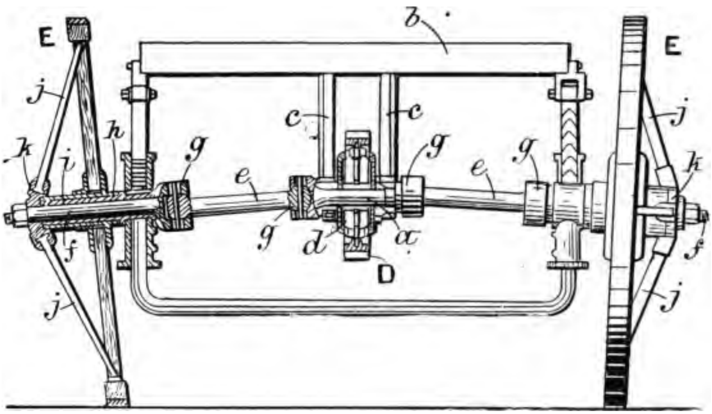

Fig. 39.—De Dion and Bouton steam omnibus. Sectional elevation of transmission gear.

pivotally mounted, or coupled through Cardan arrangements or universal joints of special construction, the extremities of connecting rods or short shafts, which in turn are coupled to short driving axles through other Cardan or universal joints, also of special construction, which admit of these axles having such an angular movement in all directions, as may be imparted by the springs supporting the vehicle, whilst the differential gear shaft rotatably mounted in its fixed brackets remains unaffected. The short driving axles are rotatably mounted in bearings in blocks, and sleeves or bushes carrying the wheels, and are rigidly connected by a bent axle below, whilst supporting the bearing springs above, and the ends of the driving axles have securely fixed to them

centre pieces or driving discs or blocks connected to the rims or felloes of the driving wheels of the vehicle through an arrangement of radial spring arms.

The Cardan joint, various modifications of which are now in common use, was devised, as is well known, by a French geometrician of that name, in the sixteenth century. The modification

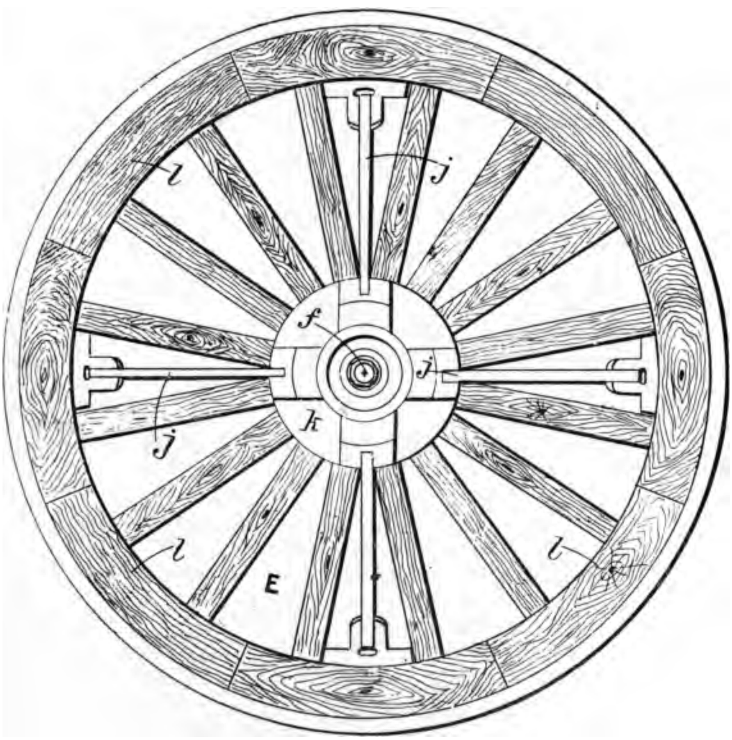

Fig. 40.—De Dion and Bouton steam omnibus. Side elevation of wheel.

designed by the Comte de Dion is of considerably greater strength than the usual patterns, and its application, as above described, to the axle of the De Dion and Bouton omnibus is shown in Fig. 39, in which *a* is a short axle journalled in two strong brackets, *c*, fixed to the frame *b* of the vehicle. This axle, *a*, carries the differential gearing *d*, having an external toothed wheel or ring, D, to which rotary motion is imparted through a toothed wheel or pinion

mounted upon the hereinbefore mentioned countershaft; *e* are the connecting rods or short shafts, which are coupled to the short driving axles *f* by means of the Cardan or universal joints *g*. The manner in which the power of the engine is transmitted to the driving wheels E is more clearly shown in Figs. 40 and 41, which represent a side elevation and horizontal central section of one of the wheels drawn to a considerably enlarged scale. From Fig. 41, it will be seen that the hub or nave *h* of the wheel E is mounted to rotate upon a flanged sleeve or bush, *i*, which is fixed, and

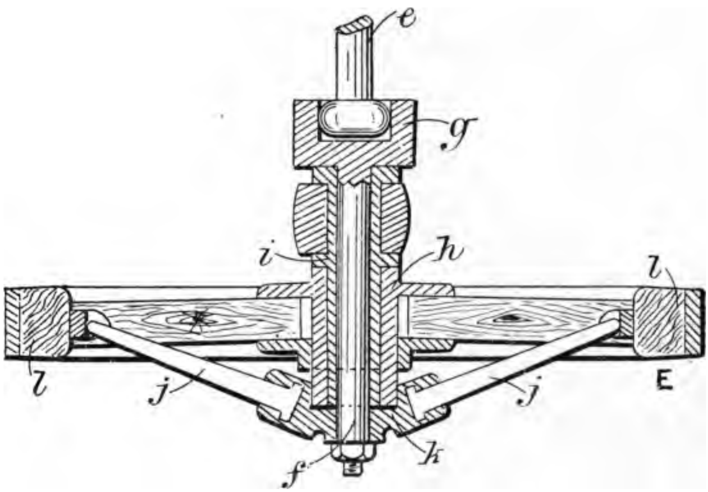

Fig. 41.—De Dion and Bouton steam omnibus. Horizontal section of wheel.

through which sleeve or bush passes the short driving axle *f*, which is coupled to the rim or felloes *l* of the wheel outside the hub or nave, in the manner shown, by four spring arms, *j*, extending radially from the centre piece or driving disc *k* secured on the projecting extremity of the short driving axle *f*. In this manner the strain of the driving effort is taken off the spokes of the wheel, and the latter are only called upon to support the weight of the vehicle.

As a result of the above driving arrangement, the wheels E are both independent of each other and of the frame *b*, and they are, consequently, free to follow all the inequalities of the road surface

without interfering with the suspension, or affecting in any way the transmission of the motive power thereto.

The front or steering wheels are 31·5 inches in diameter, and are fitted with 3·5-in. tyres, and the rear or driving wheels are 48 ins. in diameter, and fitted with 4-in. tyres. Steering is on the Ackermann principle.

The whole of the gearing and moving parts of the engine are enclosed in an oil-tight box or casing, and are arranged to run in a bath of oil therein, so as to secure lubrication of the splash description, the storage tank or reservoir for the lubricating oil being located at the side of the boiler or steam generator.

The boiler F, which is shown in Fig. 42 in vertical central section, has a water jacketed fire box, an outer annular casing, and connecting tubes, and it is placed at the front of the vehicle. It comprises two rings or annular vessels or casings, a^1, b^1, arranged concentrically, the inner one projecting above the outer one, and connected, as shown, by a number of inclined steel tubes, c^1. These two annular vessels or casings a^1, b^1, and the inclined connecting tubes c^1, form the water and steam spaces, and the steam from both the inner annular vessel a^1, and outer annular vessel b^1 is forced by a diaphragm, d^1, to pass through the upper connecting tubes, whereby it becomes more or less dried or superheated before leaving the boiler. The rings or annular vessels or casings a^1 and b^1 are closed at the top and bottom by covers, a^{1*}, b^{1*}, held together by stay bolts, a^{2*}, b^{2*}, in the manner shown.

Fuel, which is usually coke, is introduced into the furnace or combustion chamber through the central annular vessel or casing, the aperture at the top of which is closed by a suitable lid or cover, e^1, and the ashes are removed through a door, f^1, at the side of the ashpit g^1 below. The waste products of combustion escape through an uptake or chimney, h^1, communicating with a light casing, i^1, surrounding the portion of the inner annular vessel or casing a^1 that projects above the outer annular vessel or casing b^1, and the pipe j^1 for carrying steam to the engine is connected to a casting, k^1, carrying the stop valve k^{1*} and safety valve k^{2*} near the top of the steam space in the inner annular vessel or casing a^1.

The feed water is normally supplied by a pump driven by an eccentric on the rear axle, but an injector is also provided, and before entering the boiler the water is heated by being passed through a coil, l^1, in the ashpit g^1. The boiler is fitted with two

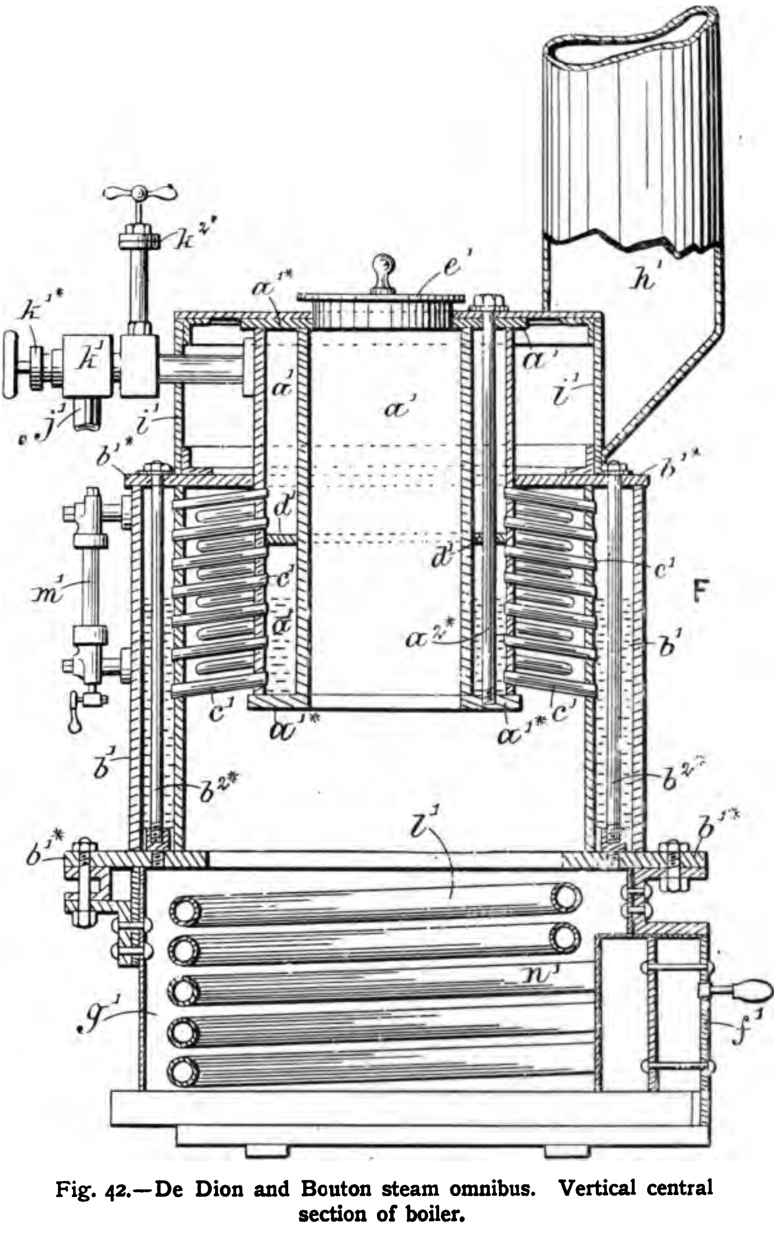

Fig. 42.—De Dion and Bouton steam omnibus. Vertical central section of boiler.

pressure and water gauges, one of which latter is shown at m^1 in the drawing.

The grate area is 1·95 sq. ft., and the heating surface about 62 sq. ft. The working pressure is 200 lbs. per sq. in., and some 6 lbs. of water are evaporated per pound of coke. Steam can be raised from cold water in about half an hour. The weight of the boiler, empty, is 7·13 cwts., and with fuel and water 9·13 cwts. A second coil, n^1, is also provided in the ashpit g,^{1} in which the exhaust steam from the engine is superheated before being discharged into the chimney or uptake h^1, so as to escape into the atmosphere as invisible vapour. The receptacle, or bunker, for fuel is situated round the boiler, and contains about 2·4 cwts. The feed-water reservoirs are located beneath the passengers' seat in the main compartment, and contain 100 gallons.

Two pairs of band brakes are provided, one of which acts upon the naves of the driving wheels, and the other on drums or pulleys keyed on the connecting rods or shafts on the outside of the universal joints and next the differential gear.

At the trial mentioned, the consumption of coke, at an average speed of 8·85 miles an hour, was 6·45 lbs. per mile, or 1·08 lbs. per ton-mile, and the water consumption was 40 lbs. per mile.

De Dion and Bouton Steam Tractors

The De Dion and Bouton steam tractors are intended for hauling heavy passenger or freight vehicles. The construction is shown diagrammatically in plan and in sectional side elevation in Figs. 43 and 44, and it will be seen to be practically a small road locomotive, which is termed by the makers a steam bogie.

The frame B is constructed of angle or V-shaped bars, and is supported upon the axles through coachsprings; it is heavy, and very strongly built, which is rendered necessary on account of the work it is intended to perform. The frame is mounted on four wheels, E, the front or steering ones being of considerably smaller diameter, and the steering being on the Ackermann principle.

The engine A is of the compound type, and is located on the frame B below the platform, that in the tractor under consideration developing 20 horse-power, and having a high-pressure cylinder 4·72 ins. in diameter, and a low-pressure cylinder 7·08 ins. in

diameter by 5·11 ins. stroke in both cases. There is an intermediate receiver between the two cylinders, and an automatic oiling device ensures the regular lubrication of the moving parts.

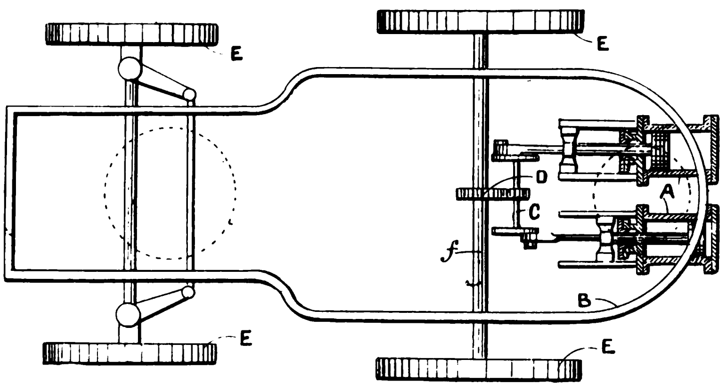

Fig. 43.—De Dion and Bouton steam tractor. Sectional plan.

When desired, full pressure of steam can be admitted to both cylinders, as in the case of the omnibus engine.

The boiler F is located, as shown on the diagrams, near the

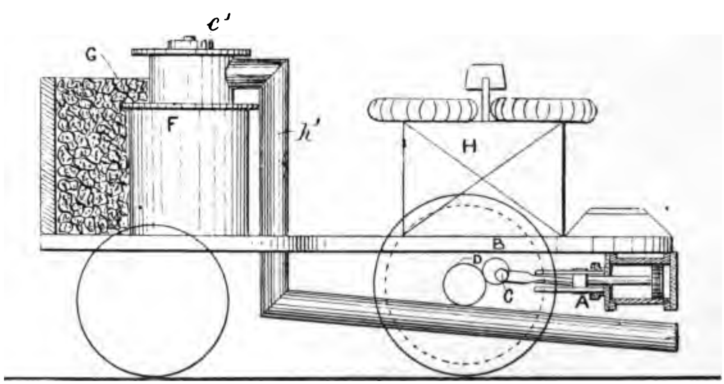

Fig. 44.—De Dion and Bouton steam tractor. Sectional side elevation.

front of the frame, and is almost entirely surrounded by the fuel bunker G. The fire-grate is 13·4 ins. in diameter, and the inner ring or annular casing 6 ins. in diameter. The connecting tubes

are of copper, 0·39 in. internal diameter by 0·12 in. in thickness, and 4·40 ins. in length. In construction, the boiler is practically similar to that already described and illustrated in Fig. 42, with reference to the steam omnibus, with the exception that instead of having an uptake, h^1, projecting upwards, as in the former case, the chimney h^1 dips downwards, and passes in a backward direction beneath the frame, discharging at the rear, as shown in Fig. 44. The feed-water reservoir H is located beneath the driver's seat.

The motion is transmitted from the engine to the driving wheels by a similar arrangement of countershaft, C, differential gearing, D, and driving axle, *f*, to that already described and illustrated in Fig. 39 with reference to the omnibus.

The weight of this tractor is 2 tons, and it is capable of drawing a load of 2·5 tons at a speed of 20 miles an hour on the level. Sufficient coke can be carried for a 60-mile run, and water for 25 miles.

The grate in the De Dion boiler is situated at about the same level as the bottom of the outer concentric ring or annular casing, the ashpit being placed below it, and, owing to its being water-jacketed in the manner mentioned, it should be one of very high efficiency. In practice, however, owing to its steaming largely under forced conditions, the efficiency is found to be thereby somewhat reduced, although the efficiency is still high.

The inventor guarantees a boiler of this type to be capable of evaporating from 4·5 to 6 lbs. of dry steam per square foot of the heating surface, and from 6 to 8 lbs. of steam per pound of coal, with natural draught.

During trials carried out by a French firm, Messrs. Sautter, Harlé et Cie., with a De Dion boiler having a heating surface of 64·5 sq. ft., a grate surface of somewhat less than 3 sq. ft., and weighing 12·7 cwts. empty, 550 lbs. of steam was produced for a consumption of 88 lbs. of coal per hour, or 6·25 lbs. of steam per pound of coal.

The results obtained with a boiler having a heating surface of 60 sq. ft. and a grate area of 1·9 sq. ft., in a 16-seated De Dion omnibus, as given in previous table (see *ante*, p. 78), shows the amount evaporated to be 6·2 per lb. of coke.

The per cent. of efficiency in the first of these instances is 48·3, and the latter 55·3.

That these efficiencies are not quite so high as those given by

some other boilers is probably due to the cause above mentioned. There can be, however, no doubt that the De Dion boiler is a steam generator having a high rate of efficiency, but on the other hand its construction is somewhat delicate, which is an objection for motor-car work, where skilled attendance is not always available. It is a boiler requiring to be carefully handled by a properly qualified person in order to ensure safety, and, as has already been observed by the writer elsewhere, is most decidedly not a boiler to be entrusted to the charge of an inexperienced driver.

Straker Steam Omnibuses

The Straker Steam Vehicle Company, of London and Bristol, are makers of steam omnibuses adapted to carry from 20 to 36

Fig. 45.—Straker standard 20-seated steam omnibus.

passengers. Fig. 45 shows the standard Straker steam omnibus for 20 passengers, and 10 cwts. of luggage on the roof. The firm also build steam omnibuses of the double-deck type.

The over-all approximate dimensions of the omnibus shown in the illustration are 20 ft. 6 ins. long by 6 ft. 6 ins. wide. The maximum speed is 10 miles an hour, and it is capable of ascending gradients up to 1 in 7 on ordinary roads, and, if desired, of drawing a trailer carrying an additional load of 12 passengers. A telescopic ladder is provided at the side of the machine, for admitting of access to the roof.

Every effort has been made in the design to secure the strength necessary to withstand the constant and heavy work to which passenger vehicles intended for public service are liable, and also to reduce vibration to a minimum. For the latter reason the vehicle is mounted on wooden wheels of the artillery pattern, and indiarubber chocks are inserted between the bearers of the body and the frame. In this manner it is claimed that the vehicle rides with great ease, and that the vibration is less than that of an ordinary street horse omnibus. In addition to the 20 passengers, the car carries two attendants, viz. driver and conductor.

In general construction the Straker steam omnibus is practically similar to the firm's standard heavy-freight steam vehicles described and illustrated in a subsequent chapter. All the parts, however, are made lighter, in order to secure the higher speed up to 10 miles an hour, and the gearing is of a higher ratio.

Scotte Steam Omnibuses and Tractors

The above makers build several patterns of steam omnibuses besides the 12-seated one mentioned in the table on p. 78.

They also make a type of vehicle or tractor carrying 8 inside and 3 outside passengers, which hauls a trailer carrying 15 passengers, besides luggage. The total weight of these vehicles without load is 6 tons 6 cwts. The tractor is 18 ft. over all, and has a frame built up of channel and T-bars, supported on the axles on four plate springs. The wheels are of wood, with iron tyres, the rear ones being 36 ins. diameter, with $4\frac{3}{8}$-in. tyres, and the front 18 ins. diameter, with 3-in. tyres. The weight of the vehicle is 3·87 tons, and this is pretty equally distributed on the wheels.

The engine is a vertical one, and has two cylinders $4\frac{1}{2}$ ins. diameter by $4\frac{3}{4}$ ins. stroke, developing 16 horse-power at 400 revolutions per minute, and weighing about 6 cwts. The cut-off can be varied from $\frac{3}{8}$ stroke to $\frac{3}{4}$ stroke, and ordinary link motion reversing gear is provided. Either of two pinions on the crank shaft can be thrown into gear with toothed wheels on the countershaft, thus giving speeds of 7·5 and 3·25 miles an hour. The external toothed wheel of the differential gear is driven by a pinion on the above-mentioned countershaft through a pitch chain, and the differential gear is mounted on a countershaft driving

each of the rear wheels independently through ordinary chain gearing.

The boiler is of the Field type, with vertical tubes, and is adapted to work at a pressure of 170 lbs. per square inch. It has a grate area of 1·6 sq. ft., and a heating surface of 120 sq. ft.; its weight, when empty, is 9·8 cwts., or, with water, 11·16 cwts. Pressure can be raised from cold in slightly over half an hour. The fuel consumption on trial was 72 lbs. of coke per square foot of grate area per hour, and the evaporation 610·6 lbs. of steam to 115·2 lbs. of coke or 5·3 lbs. of water per pound of coke. Gauge pressure, 170 lbs. per square inch.

An ordinary feed pump, an injector, and a water circulator are provided. The ashes, which fall into an enclosed ashpit, are damped by the water resulting from the condensation of steam in the feed-water heater.

The engine and boiler are placed near the front of the vehicle, and the coke bunker, which is right in front, contains 270 lbs.

Three water tanks are provided, two under the passengers' seats and one beneath the footboard.

Two brakes are fitted to the vehicle, viz. a screw brake, working shoes against the tyres of the driving wheels, and a foot brake, operating Lemoine brakes coiled twice round the drums.

The steering is operated by a hand wheel working a screw through a jointed rod and mitre gearing, arrangement being made to allow free vertical movement of the front axle. By working in this manner a nut backwards and forwards on the screw the front wheels are moved through bars and levers pivoted to the ends of the fixed axle.

Weidknecht Steam Omnibuses

An example of this type of omnibus is one adapted to accommodate 16 passengers and 500 kilogrammes, or 9·8 cwts., of baggage.

The overall length of this vehicle is 18 feet, and the weight 5 tons 6 cwts.

The frame is constructed of light channel iron girders, supported in front through two leaf springs on the front axle, and

the wheels are constructed with wooden spokes and felloes, 1·400 m., or about 55 ins., in diameter, with 99 mm., or 3·86 ins., iron tyres and are used for driving. The rear axle is secured directly to the frame, thinned down at that end to give a certain amount of elasticity, and the wheels are 1·100 m., or 43·27 ins., in diameter.

The engine is horizontal, with two cylinders, each 4·92 ins. diameter by 4·92 ins. stroke, with cranks set at 90 degrees. It is fitted with variable expansion gear and reversing gear of the Sohn type, worked by a lever placed between two toothed segments. A variation of cut-off from 0·1 to 0·83 of the stroke can be effected. At a speed of 350 revolutions per minute the engine gives 19·7 horse-power. A cast-iron box or casing, open at the top, partially encloses the moving parts.

The boiler is a vertical one of rectangular section, and fitted with both water and smoke tubes. There are 87 1·18-in. diameter water tubes, which cross the upper part of the firebox diagonally. The uptake consists of 16 smoke tubes, also acting as stays to the crown of the firebox and boiler shell. This boiler has a heating surface of 64 sq. ft., and 3 sq. ft. of grate area, and is claimed to evaporate 572 lbs. of water per hour at an average working pressure of 150 lbs. per square inch. At the before-mentioned tests (see previous table on p. 78) the evaporation was 6·5 lbs. of water per pound of coke. Gauge pressure, 170 lbs. per square inch. The fuel, which is usually coke, is fed to the furnace by an automatic stoker, which has to be supplied with fuel every 2½ miles. The water tank holds 62 gallons, and the coke bunker at the side of boiler 1·18 cwts.

Power is transmitted from the differential gear countershaft by ordinary chain gearing, and two brakes are provided, viz. an ordinary screw hand brake, and a Lemoine coiled wire hand brake, operating on drums secured to the driving wheels. Speed-change gearing allows of variations from 9·3 to 4·65 miles per hour.

The steering is effected by moving the rear wheels, which are pivoted at the ends of the fixed axle, through a hand wheel on a vertical shaft carrying a pinion meshing with a rack on a rod, the movement of which is transferred to the pivoted axles by a steering lever and connecting links.

The wheels adopted by Mr. Weidknecht are shown in Figs.

46 and 47, the first being a part vertical central section, showing one of the rear or driving wheels, and the latter a similar view of one of the front or steering wheels, both of which are, as will be seen from the dimensions already given, of considerably larger diameter than those usually employed. The weight sup-

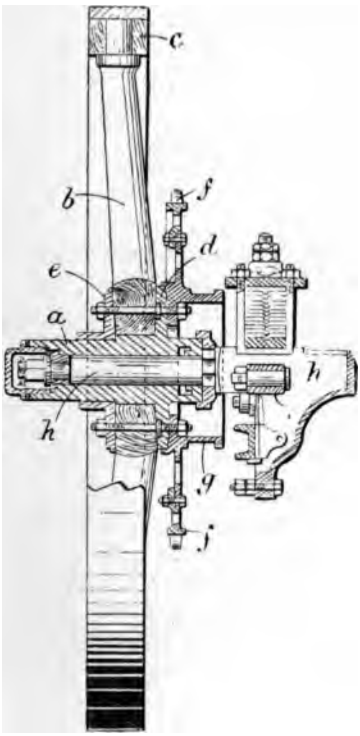

Fig. 46.—Weidknecht steam omnibus. Part sectional view of rear or driving wheel and axle.

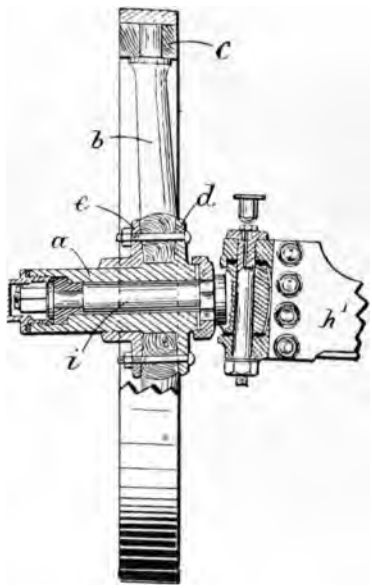

Fig. 47.—Weidknecht steam omnibus. Part sectional view of front or steering wheel and axle.

ported upon each of the wheels is 1750 kilogrammes, or 1 ton 14·3 cwts., when the vehicle is loaded. The naves *a* are made of bronze, and form axle boxes of a patent self-oiling type, which, however, does not differ in any material particular from the well-known Collinge axle box, and the spokes *b* are secured to the rim or felloes *c* by mortise and tenon joints, the

latter being formed with shoulders. The spokes *b* are secured in the nave or hub *a* between two plates or flanges, *d* and *e*, the one *d* being integral with the hub *a*, and the other *e* being clamped to the former by bolts in the usual or ordinary manner. The central portions of the chain wheels *f* for communicating motion to the driving wheels are formed integral with the brake drums or pulleys *g*, and are mounted on the naves or hubs *a*.

The driving wheels are rotatably mounted on a fixed axle, *h*, and the steering wheels are mounted on short axles, *i*, pivoted to a fixed central axle, h^1.

The increased diameter of the wheels would most certainly seem to be a move in the right direction, and is said to have given the satisfactory results that were to be anticipated from the experiments of Morin and others with reference to traction on common roads, that the resistance opposed to rolling is in the inverse proportion to the diameter of the wheels. Indeed, even without the authority of these experiments, it is only rational to suppose that wheels of large diameter would admit of the obstacles due to inequalities of the surface being more readily overcome, and with less jarring or jolting than is the case with those of smaller diameter, and, moreover, wheels of large diameter, owing to their rotating at a slower rate of speed, raise far less dust on dusty roads, an advantage of no little value.

It is true that wheels of large diameter are not so strong as those of a smaller diameter, or, at least, that, to make them so, they would have to be of inordinately heavy construction, but inasmuch as they are subjected to less severe strains, this objection does not seem to be of any great moment, and there should be no difficulty in constructing wheels of large diameter strong enough to bear the strains to which they will be liable, and at the same time light enough so as not to render their weight an objectionable feature. With respect to the greater ground space occupied by wheels of large diameter, it may be pointed out that as heavy passenger vehicles are only required to run upon wide, or, at least, moderately wide, roads, this is a point of practically no importance, and is amply compensated for by the greater stability ensured by the wider wheel base.

THE SERPOLLET SYSTEM

Although Mr. Leon Serpollet has of recent years turned his attention to the perfection of steam tramway vehicles and motor railway carriages, his steam generator and engine possess such possibilities for use in steam omnibuses adapted to run on common roads that this brief account of the latter would be incomplete without some reference to the Serpollet system.

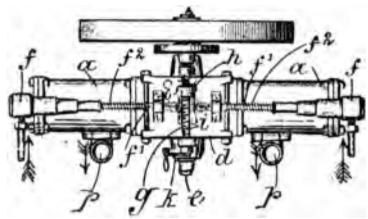

Fig. 48.—Serpollet system. Plan view of engine.

The latest type of Serpollet motor is especially designed to work with the highly superheated steam supplied by the flash or instantaneous generation type of boiler that bears his name, and the use of which forms so important a feature in the system. The engine, which is shown in plan and side and end elevation in Figs. 48, 49, and 50, has two single-acting cylinders, *a* (one of which is shown in vertical central section in Fig. 49), so arranged

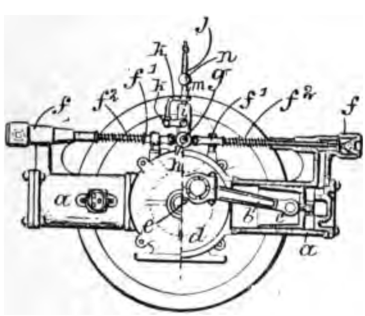

Fig. 49.—Serpollet system. Sectional side elevation of engine.

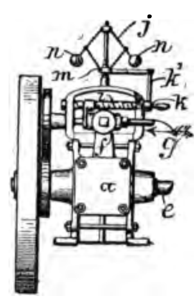

Fig. 50.—Serpollet system. End elevation of engine.

opposite to each other that the two piston rods work on to the same crank shaft. The piston rod *b* is pivoted in the bottom of the hollow piston or plunger *c*, a special type of crosshead connecting both piston rods to a single crank working in an oil-tight

crank box or chamber, *d*, which constitutes the frame of the engine, and through glands in which crank box or chamber the crank shaft *e* extends as shown. *f* are the steam admission valves, which are placed on the tops of the cylinders *a*, and the spindles f^1 of which are controlled by means of a small cam shaft, *g*, mounted centrally between and above the cylinders *a*, and to which shaft rotary motion is imparted by toothed gearing from the crank shaft, both shafts running at the same speed. *h* is a cam sleeve, which is so mounted on the shaft *g* that it is capable of longitudinal displacement thereon, whilst being obliged to rotate therewith. This displacement can be effected by means of a specially shaped nut threaded on a screwed spindle, *i*, which latter is controlled by a centrifugal governor, *j*, through the crank arm *k*, connected, as shown, by the lever arms k^1 to the sliding sleeve *m* of the governor, so that the movements of this sleeve under the action of the balls *n* will be imparted to the cam sleeve *h*, and the latter moved longitudinally of its shaft, to vary the action of the cam upon the valve spindles, and impart a greater or lesser movement to the latter. The extremities of the valve spindles f^1 are provided with antifriction rollers, which bear against the cam *h*, the spindles being normally retained in that position by springs, f^2. By this means it is stated that the steam admission can be varied from 0 to 80 per cent.

For reversing, a second cam, *o*, is provided, which can be brought into position opposite the rollers on the valve spindles when it is desired to reverse, by means of the crank arm *k*, suitable provision being made for effecting this operation from the driver's seat.

The exhaust takes place through the orifices *p* in the cylinder walls, near the termination of the strokes of the pistons, all excess of steam above the pressure of the atmosphere escaping through the ports or orifices *p* when communication is made between the latter and the spaces at the rear of the pistons. Such steam as remains in the cylinders at atmospherical pressure is not exhausted, but, on the return strokes of the pistons, is compressed, thus forming a cushion, and should the pressure exceed that of the steam in the boiler, this steam will be forced back through the valves *f* into the steam pipe.

Another method adopted of effecting the above object is shown in the sectional view, Fig. 51. This latter arrangement is claimed

to get rid of all troublesome condensation in the cylinders, without interfering with the admission of steam thereto. In this case an exhaust orifice or port, *p*, is provided in an extension, c^1, on the piston *c*, working in a small cylinder a^1.

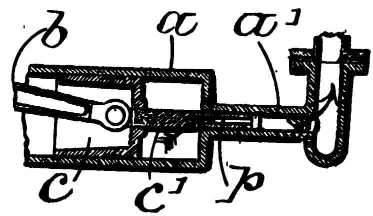

Fig. 51.—Serpollet system. Vertical central section showing alternative arrangement of exhaust.

The latest type of Serpollet boiler or steam generator is shown in vertical and horizontal section in Figs. 52 and 53. This boiler has undergone very considerable modification since its first introduction. As originally constructed, it consisted of a number of thick tubes rolled into a kidney-shape in transverse section, and connected together by bends, or return heads, on the exterior of the furnace. A very narrow space was left in the interior of these tubes for the water to pass through, and the concave sides of the tubes were placed so as to receive the flames from the furnace.

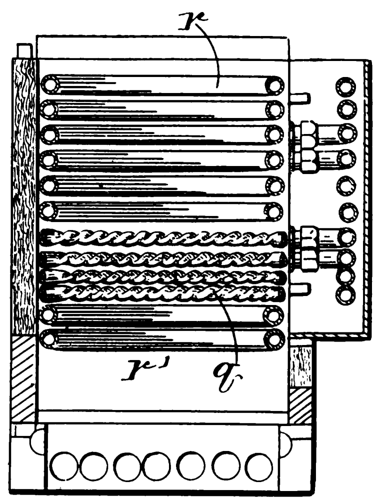

Fig. 52.—Serpollet system. Vertical section of boiler or steam generator.

The modified arrangement of boiler shown in the illustrations comprises two portions, the first portion, which is most exposed to the heat of the furnace, being composed of thick steel tube, *q*, twisted into a helical form, and so placed as to intercept, as far as possible, the flames from the furnace r^1, whilst the second or upper portion is composed of any ordinary coil, *r*, of thinner section cylindrical tube.

The boiler was originally fired with coke, but liquid fuel is now employed, and Mr. Serpollet has devised an ingenious device for

automatically and synchronously controlling the supplies of oil to the burner, and water to the boiler.

The type of burner employed is the Longuemare, shown in

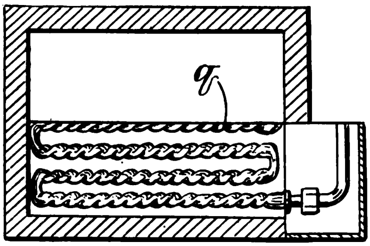

Fig. 53.—Serpollet system. Horizontal section of boiler or steam generator.

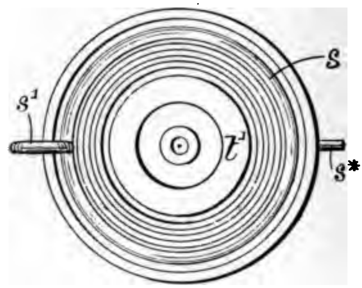

Fig. 54.—Longuemare liquid fuel burner used in Serpollet boiler. Plan view.

plan and vertical central section in Figs. 54 and 55, which consists of a row of coils, *s*, forming a vaporizer, to which the oil or spirit delivered through the pipe s^* is passed, and from which it is delivered in the form of vapour through a pipe, s^1, way, or passage, s^2, and regulable needle valve *t*, to the burner t^1.

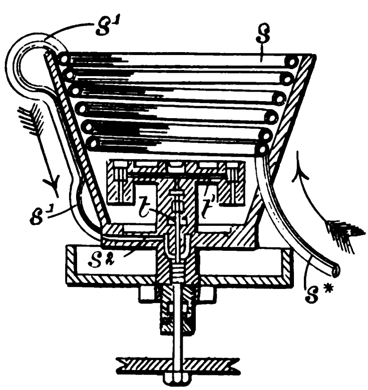

Fig. 55.—Longuemare liquid fuel burner used in Serpollet boiler. Vertical central section.

The oil and water controlling device, shown in Fig. 56, comprises an oil or petrol pump, *u*, and a water pump, *v*, the pistons or plungers, u^1, v^1, of which are coupled by short connecting rods, u^2, v^2, the one to a lever, *w*, and the other to a sliding block, w^1, mounted upon this lever, which latter is pivotally connected at w^2 to a rigid bar, *x*, the distance between the pivots, and the diameters of the pump plungers being such that the amount of petrol pumped by the petrol pump *u* at each stroke will be exactly sufficient to

vaporize and superheat the amount of water pumped at each stroke of the water pump *v*.

In order to be enabled to allow for any variations that might occur owing to differences in temperature and in the quality of the petrol, etc., a screw-threaded spindle, *y*, is provided for adjusting the position of the sliding block w^1, and, consequently, through the connecting rod u^2, varying the stroke of the plunger or piston u^1 of the petrol or oil pump *u*. In this manner, the proper proportions between the supply of oil or petrol and water can be maintained or suitably modified, as desired.

In addition, however, to the above adjustment, it is also

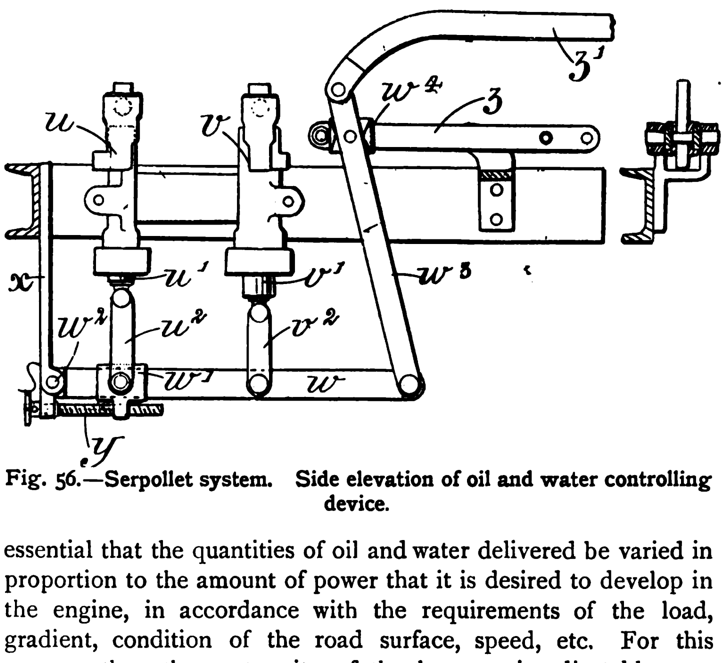

Fig. 56.—Serpollet system. Side elevation of oil and water controlling device.

essential that the quantities of oil and water delivered be varied in proportion to the amount of power that it is desired to develop in the engine, in accordance with the requirements of the load, gradient, condition of the road surface, speed, etc. For this purpose the other extremity of the lever *w* is adjustably connected by means of a connecting rod or link, w^3, and sliding block or piece, w^4, with the oscillating bar or lever *z*, through which reciprocating motion is imparted to the lever *w*, and, therefore, through the connecting rods u^2, v^2 to the plungers or pistons u^1, v^1 of the oil pump *u*, and the water pump *v*. This oscillating bar or lever, *z*, is pivoted at or about its centre, and motion is imparted to

it by means of an eccentric keyed on one of the shafts of the transmission gearing. By means of a lever, z^1, one end of which is jointed to the upper extremity of the connecting rod or link w^3 above the sliding block w^4, and the other extremity of which extends to within convenient reach of the driver, the position of the sliding block w^4 upon the oscillating bar or lever z can be altered, and the length of the arm of the lever acting upon the lever w lengthened or shortened, as required, the throw of the latter, and, consequently, the strokes of the pumps u and v, obviously depending upon the radius of this lever arm.

By either placing the oil reservoir at a somewhat higher elevation than the burner, or by providing a slight pressure therein, the oil will pass slowly to the burner whilst the vehicle is at rest, without being pumped or forced thereto by the pump u, and will raise the valve t sufficiently to allow of the passage of enough oil to maintain a small flame and keep the generator ready to get up steam immediately when required.

The steam consumption of the Serpollet engine is said to be low, that of a two-cylinder engine, with cylinders 80 mm. (3·15 ins.) diameter, by 80 mm. (3·15 ins.) stroke, developing 4-horse-power at 510 revolutions per minute, being 10 kilogrammes, or 22 lbs., of steam per horse-power hour.

The results obtained with a Serpollet tram with trailer carrying 100 persons and luggage, and having an engine with cylinders 5·9 ins. and 5·9 ins. by 6·3 ins., are given in the previous table on p. 78, the boiler used being in this case one of the old pattern, and the fuel, coke.

PETROL OMNIBUSES

The commercial success of any passenger transport scheme, as, indeed, also that of any scheme having for its object the transport of goods, is practically entirely dependent upon the lowness of the running and maintenance charges.

Theoretically the internal combustion engine, having a high rate of efficiency, should prove a suitable power for this purpose, but in practice the results obtained from actual experience in running public service omnibuses propelled by this source of power, do not seem to have always given the satisfactory results that might have been anticipated, and the internal combustion

engine, in its present stage of development, does not appear to have completely solved the problem of mechanically propelled omnibuses adapted for the accommodation of considerable numbers of passengers, although its successful application to lighter vehicles is now an established fact.

There are, nevertheless, a number of paying services of petrol omnibuses running, especially in the provinces. In London, the London Power Omnibus Company, Limited, has for some time past had a service of petrol omnibuses between Kilburn and the Marble Arch, which service they have recently extended to Cricklewood. The Motor Omnibus Company, Limited, commenced early this year (1905) services of double-decked omnibuses between Kilburn (Brondesbury) and Charing Cross, and elsewhere. The General Omnibus Company have, at the time of writing, 100 motor omnibuses on order, which will shortly be put in service. And several other companies are, or will soon be, running motor omnibuses. In fact, by the time this work is out of the hands of the printers motor omnibuses will doubtless be in a fair way to becoming the rule instead of the exception in the London streets.

EXAMPLES OF PETROL OMNIBUSES

Stirling Petrol Omnibuses

Messrs. Stirling, Limited, of Granton-Harbour, Edinburgh, build motor omnibuses, of various sizes, propelled by internal combustion engines, and adapted to seat from 14 to 28 passengers.

The standard type of Stirling Petrol Omnibus (Fig. 57) is propelled by a four-cylinder internal combustion engine of the Stirling type, having two independent ignition devices, and developing 24-horse-power. The transmission gear, which is of a special design made by the firm, provides three changes of speed, with a maximum one of 14 miles an hour, the average speed being about 12 miles an hour. The cooling is effected on the natural circulation system, the cooling water being stored in a tank or reservoir capable of holding about twelve gallons of water, and located at a high level in front of the dashboard, practically, indeed, forming part of the dashboard itself. This supply of cooling water has been found amply sufficient in practical working to maintain the engine in a satisfactory condition, and to prevent any undue rise

in temperature, it being only necessary to add a little fresh water about once a week. The engine is placed below the driver's footboard. The wheels are artillery pattern fitted with solid indiarubber tyres, and the weight of this omnibus having a seating capacity for fifteen passengers and the driver, or sixteen persons in all, complete with fuel, water, and all accessories, is 1 ton 18 cwts. Two powerful independent brakes are provided, one of which is a quick-action one, operated by a pedal on the second shaft. The other is a type of spring side lever brake, engaging the driving rings of the rear wheels, which has been designed and patented by the makers. By means of a special arrangement of governor, provision is made for rendering it impossible for the driver to exceed the maximum speed.

Fig. 57.—Stirling 16-seated petrol omnibus.

The body of the omnibus is supported on long flexible springs, which render travelling easy, and make the vehicle more comfortable. For hot weather the glass windows at the side are so constructed that they can be removed when desired.

Rails are provided at the sides of the roof, which latter is raised to form a higher central gangway, and light luggage can be carried on it, an iron ladder fitted at the front end of the vehicle affording easy access for loading and unloading. This provision for luggage, however, is only made on omnibuses intended to run in rural districts, and is not shown on that illustrated.

Stirling petrol omnibuses have been running in Scotland for a considerable time, and, it is said, with great success. In 1903 a service of these omnibuses was started in London by a syndicate, the route being from Cricklewood, through Kilburn, to Oxford Circus. The average time occupied in the double journey was one hour; a record time of 15 minutes for the single journey was, however, made on one occasion. The time taken by the horse-drawn omnibuses is about one hour for the single journey.

After running for a few months this service was discontinued. The service between Brondesbury and Oxford Street was improved and renewed by another syndicate, and, with the exception of a fire that damaged several of the omnibuses, this service has been successfully continued up to the present time.

So far as the running of the vehicles is concerned, the writer has been informed, there is no fault to find. And it is to be noted that the severe competition on this short route, and the resulting low fares, render the earning of satisfactory dividends a difficult matter. The possibility of continuing and even improving the service is very satisfactory evidence, therefore, of the possibilities of petrol omnibuses.

De Diétrich Petrol Omnibuses

A De Diétrich petrol omnibus gave very satisfactory results at the heavy-weight trials in France in 1903, both in the preliminary fuel consumption tests and in the run to Nice. The vehicle is very strongly built in order to enable it to successfully withstand the heavy strains to which omnibuses are subjected when on service, otherwise it is practically on the same lines as the 24-horse-power touring car, built by the same makers.

The omnibus is fitted with a 24-horse-power four-cylinder engine, and has magnetic ignition. The change-speed gear provides for four speeds and a reverse.

The weight of the vehicle (which is adapted to accommodate 12 persons), including a load of 13 cwts. 18 lbs., is 2 tons 10 cwts. 2 qrs. 4 lbs. The wheels are of the artillery pattern, and are fitted with large pneumatic tyres.

The De Diétrich omnibus was the only vehicle that went through the above-mentioned trials without accident of any description, and the consumption of petrol was low, being about 6·5 gallons for the run of 52·6 miles. In the long run the average speed attained was 18 miles an hour.

Halcrow-Vincke Petrol Omnibuses

The Halcrow-Vincke petrol omnibuses have frames of the standard type made by the firm of that name, whose works are at Malines, Belgium.

The body of the standard omnibus is divided into two classes of compartments, providing accommodation for 6 passengers and 10 passengers respectively. The driver's seat is situated above the engine, and is partly protected from the weather by carrying the roof over it. The weight of the vehicle in running trim is about 32 cwts. The tyres are solid indiarubber.

Motive power is provided by a 12-horse-power two-cylinder vertical engine. The main clutch is of the internal cone pattern, and the change-speed gear is of the ordinary sliding toothed-wheel type. Transmission to the rear wheels is effected by means of side-chain gearing. Three speeds in a forward direction and a reverse are provided, the maximum being 15 miles an hour. The steering is of the rack and pinion type, having a vertical steering pillar and wheel.

Other Petrol Omnibuses

Amongst other petrol omnibuses now on the market, mention may be made of those of the following makers: Straker and Squire, London, double-decked type; Thornycroft Company, 24-horse-power petrol omnibuses, double-decked type; The Lancashire Steam Motor Company, petrol omnibuses; Maudslay Motor Company, 14-horse-power petrol omnibuses; Crossley Leyland, petrol omnibuses; and the Brush Electrical Engineering Company, double-decked petrol omnibuses. This latter vehicle possesses the special feature of having the entrance for the passengers located at the front end, thus enabling the services of a conductor to be dispensed with.

Omnibuses of both the open and closed types, and brakes adapted to be propelled by internal combustion engines, are also built by Benz, Milnes-Daimler, Peugeot, Delahaye, De Dion, Bouton and Company, and others.

Unfortunately, space does not admit of giving even brief descriptions of these vehicles, but it may be observed that most of the well-known makers of petrol vehicles build omnibuses with running mechanisms practically identical in construction with those of their light pleasure and goods delivery vehicles, the main difference being that, of course, the frames of the motor omnibuses are much heavier and the engines are of considerably greater power, in order to provide for the propulsion of the heavier vehicles.

COMPOUND OR PETROL-ELECTRIC OMNIBUSES

Motor vehicles propelled by electricity generated on the cars themselves by dynamos driven by internal combustion engines, and where the surplus power developed when descending hills, etc., is stored in accumulators for use in emergencies, are built by the Fischer Motor Vehicle Company, New Jersey, U.S., Jenatzy, The Compagnie de l'Industrie Electrique et Mecanique, of Geneva, and others.

Fischer Petrol-Electric Omnibuses

Omnibuses of that kind or class wherein electric transmission is employed, the power generated by a hydro-carbon motor or internal combustion engine being used as a prime mover to operate a dynamo or dynamos, and the electric current generated

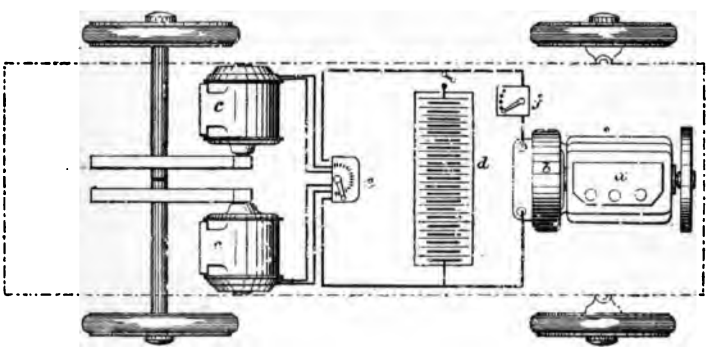

Fig. 58.—Fischer petrol-electric omnibus. Diagram of running mechanism.

by the latter utilized to propel the vehicle through an electric motor or motors, designed by the Fischer Motor Vehicle Company, of Hoboken, New Jersey, U.S., have lately been brought to this country by the Fischer Motor Vehicle Syndicate, of London.

This type of mechanically propelled vehicle is said to have proved very successful in the United States, and tests made

in London some time ago by the London General Omnibus Company are stated to have been quite successful—at any rate, so far as the satisfactory running of the vehicle was concerned.

The omnibus subjected to the latter tests was one of the double-decked type, adapted to carry 10 inside and 18 outside passengers, or 30 persons altogether, including the driver and conductor. The wheels are of the artillery pattern, the front being 36 ins., and the rear 40 ins. in diameter, and the wheel base 9 ft. 3 ins. The approximate weight of the vehicle is 5 tons 2 cwts. 3 qrs.

The general principle of the Fischer system is shown in the diagram Fig. 58, in which *a* indicates an internal combustion engine, and *b* a dynamo direct coupled thereto; *c* electric motors, *d* an accumulator or storage battery, *e* a controller, and *f* a switch for starting the engine.

The internal combustion engine *a*, which is mounted longitudinally or lengthwise of the frame, is of the three-cylinder vertical type, with the cranks set at angles of 120 degrees to each other, and is directly coupled to the dynamo *b*, which is mounted in front of it. It has an enclosed crank chamber, with an inspection aperture, closed by a suitable lid or cover at each side, and the crank-shaft, which, owing to the position of the engine, is placed at right angles to the axles, has a fly-wheel mounted as shown on its rear extremity. The inlet valves, which are located above the exhaust valves, are operated by the pressure of the atmosphere.

Ignition is effected by plugs of the high-tension type, and the commutator is driven through bevel gearing from the cam shaft.

The storage battery or accumulator *d* consists of fifty chloride cells, with a combined capacity of 90 ampère hours. When starting the internal combustion engine the storage battery *d* is switched on to the dynamo *b* by the driver, who can in this manner effect the operation from his seat. During running the storage battery is connected across the dynamo terminals, thus keeping the speed of the engine practically constant, any excess of current over and above that required by the electric motors *c* being stored up in the storage battery or accumulator. A combined ammeter and voltmeter is mounted on the driver's seat, the latter being constantly connected across the dynamo terminals.

The controller *e* is of the parallel series type, having five forward and three reverse positions, by means of which the forward

movement can be varied up to 10 miles an hour, and the reverse up to 5 miles an hour. The forward positions comprise the following connections, viz.: First, the motors in series with a starting resistance introduced; second, the motors in series with resistance cut out; third, the armatures in series and the fields in parallel; and fourth, the motors in parallel. In addition to this, however, toothed wheels fixed on the outer ends of the motor shafts gear with correspondingly toothed wheels on intermediate shafts, and through toothed pinions on the latter, with toothed wheels secured to the rear, or driving wheels. The above change-speed gear is enclosed in a suitable casing, and by its means and the controller combinations, practically any desired speed can be provided for. The controller operating lever is connected with a contact-making drum, and a suitable catch arrangement prevents the lever from being moved into the reverse positions without releasing this catch. The electric motors are shunt-wound and bipolar, and are completely enclosed, being pivotally supported from the rear axle, and through springs from the main frame, and rigidly connected together, although their shafts are independent of each other. On the inner extremities of the motor shafts, brake drums are provided, a pedal on the right of the steering pillar allowing of both brakes being applied simultaneously, and the former being capable of being connected by a two-way switch, so as to show the amount of current being generated, or the amount being used by the motors.

The springs supporting the main frame are semi-elliptical, and a transverse spring is provided at one end of the front ones. The front axle is of the girder pattern, the steering axles being hinged or jointed to it, and the front springs being bolted to it so that they pass between the upper and lower members of the girder. Steering is on the Ackermann principle, through a rack coupled by a connecting rod to the front wheels, and a hand-wheel mounted on the top of a vertical shaft, having at its lower extremity a pinion gearing, with the above rack.

It will be seen from the above that the internal combustion engine *a* is the primary source of power, the latter being transmitted to the driving axle by means of the electricity generated. In this manner it is claimed that the advantages of the two systems are retained, whilst their objectionable features are got rid of, or at any rate reduced to a minimum.

According to the makers, the nett efficiency between the prime mover and the wheels, with this system of transmission, is 64 per cent., which bears favourable comparison with mechanical transmissions now in use. The above percentage is estimated on the basis of the bulk of the electric current going directly from the dynamo *b* to the electric motor *c*, and taking the efficiency of the dynamo and electric motors at 80 per cent. each, a figure somewhat under that usually guaranteed by manufacturers.

The device for controlling the speed and power of the engine consists of an arrangement of levers which can be operated from the driver's seat, and by means of which the time of ignition and the richness of the explosive mixture can be varied at the will of the operator.

The main advantage possessed by this system is that it admits of the internal combustion engine being run at a constant speed, thus enabling the gas and air mixtures to be permanently set so as to secure as near perfect combustion as possible, and in this manner both effecting a saving in oil consumption and preventing the usual abominable stench given off from the exhaust where more or less imperfect combustion results from the ever-varying conditions under which the engine is called upon to work when the power is utilized in the usual manner. It is also stated that with this system a smaller engine can be used, viz. one of one-third the power that would be otherwise required, and it is, moreover, self-starting—a not inconsiderable advantage.

So long as the vehicle is running on a level surface, under normal conditions, the whole of the electric current generated passes direct from the dynamo to the electric motors. When running downhill, however, travelling at slow speed: in fact, whenever less power is required for the propulsion of the vehicle, the surplus current is stored in the storage battery or accumulator. This store of energy is drawn upon whenever extra power is required, such as when ascending steep gradients, starting heavy loads, on bad roads, etc. It will, of course, be understood that the above action is completely automatic, and takes place quite independent of the driver. The output of the hydro-carbon engine being constant, no mechanical governor is required, but for the purpose of economy, and to prevent too heavy a current from going into the storage battery, a contrivance is provided, by

which the hydro-carbon engine is automatically throttled when the vehicle is at rest.

It is stated that the storage battery required in this system being one of small capacity, it is practicable to build one that will have a comparatively long life, and as applied in this combination it is seldom required to furnish current for more than a few minutes at any one time.

As is well known, ordinary use is necessary to keep a storage battery in good condition. It is discharging too low, and then allowing it to stand without immediate recharging that gives rise to sulphating and buckling, and causes rapid destruction. Under the conditions existing in this vehicle, it is therefore hardly possible for the storage battery to become exhausted.

The reason for the storage battery not becoming over-charged, as might be anticipated, when the vehicle is running with a light load, is accounted for by the fact that, whilst it takes a pressure of $2\frac{1}{2}$ volts to charge the cell of a storage battery, during discharging the pressure is practically 2 volts, thus making a difference of 20 per cent. in voltage between charging and discharging, and, moreover, as in automobile work, the voltage is usually permitted to run down to 1·7 volts per cell before the battery is considered to be anywhere near exhausted; this makes a still greater difference.

A well-charged battery is what may be considered as being lively, that is to say, the solution is rich in acid, which makes the internal resistance low, and consequently the conductivity and capacity for work high. On the other hand, a nearly discharged battery is what may be termed sluggish, and although it may register on the voltmeter when not in use, the capacity for work is absent, because the act of discharging drives the acid out of the solution and into the plates, thus leaving the solution a comparatively poor conductor, which is the reason that a nearly discharged battery does not take hold readily.

The electric motors used in automobile work have a speed corresponding to the voltage, that is to say, when the voltage is high the speed will be high, and vice versa. Consequently when the vehicle is running with so light a load, or on a down gradient, that there is power to spare, the voltage will climb up to the highest possible point, and the motors, and consequently also the vehicle, will run faster, and owing to the increased speed, a greater amount of power will be consumed. When, however, the

vehicle is heavily loaded, or is mounting a steep gradient, so that an excessive amount of power is required for propulsion, the engine will slow down, and the voltage will drop sufficiently to admit of the battery furnishing the extra power demanded. At this reduced voltage, the motors, and, consequently, the vehicle, will run at a slower speed, the result of which is claimed to be that even with a heavy load considerably less power is used in proportion.

Under normal conditions the engine works with a constant power output; the current and pressure, however, vary according to the conditions. For example, if the voltage is high, the current outputs will be low, whilst if the voltage should be low, a corresponding increase in the current output will take place. In this manner it is claimed that there is a general tendency to equalize matters all round, that is to say, that the motors are constantly endeavouring to adapt themselves to the amount of power furnished by the engine.

Practical working has shown that the damage done to storage batteries by overcharging is trifling in comparison with that resulting from allowing them to run down too low. The result of overcharging is merely the evaporation of the solution and the boiling of the battery, that is to say, that the greater part of the acid will be driven out of the plates, and inactive material has been converted into active material. An additional current sent through the batteries is used up in evaporating the water of the solution, which can be easily replenished. During the discharge the process is reversed, the acid acts on the active material and reduces it to inactive, and when the battery is in that condition the acid will combine and form sulphate of lead, which takes up more room than the original material, thereby causing the plates to warp and pull themselves to pieces. When this sulphate is once formed, it can never be brought back again to active material, and this is the reason that batteries lose their capacity if allowed to stand for any length of time after being discharged, without recharging.

As regards the cost of running the Fischer motor omnibus, results deduced from actual working in this country are not at present available. For purposes of comparison, however, it may be mentioned that in the case of a motor waggon on the Fischer principle, running in New York, the cost of working has been

found to be $2\frac{1}{2}$ cents., or $1\frac{1}{4}$d., per mile on average roads. This vehicle weighs four tons, and is capable of carrying a load of eight tons. It is driven by a 12-horse-power internal combustion engine, the power generated by which is transformed into electricity by means of a dynamo, and operates a pair of 7·5-horse-power electric motors, one of which is geared to each rear wheel. The maximum speed is six miles an hour. It may be mentioned that the motors are guaranteed to carry 100 per cent. over-load for one hour, and will in cases of emergency work up to over 50 horse-power for short periods.

In conclusion, it may be remarked that the weight of the machinery required in the Fischer compound system is not by any means so much in excess of that of an internal combustion engine only, operating direct, as might be expected, as in the former case the engine required is of much smaller capacity than in the latter. It is, nevertheless, undoubtedly, somewhat heavier than would be the case were the propelling power derived from an internal combustion engine fitted with the usual change-speed mechanism, without the electric transmission, and it would appear probable that the cost of the renewal of the storage batteries, the maintenance of the electric generating and driving mechanism, and the additional repairs and renewals required for the proper maintenance of the vehicle and tyres, due to this extra load, would be, therefore, somewhat higher in the case of the compound system.

Against this, however, there is the advantage derived from the abolition of the highly objectionable change-speed gear, and the other advantages already enumerated. There is, furthermore, the reserve stock of electric power in the storage battery to fall back upon in the event of a failure—a by no means unlikely occurrence—of the internal combustion engine, which would generally be sufficient to carry the 'bus to its destination.

Jenatzy Petrol-Electric Omnibuses

The Jenatzy compound petrol-electric motor omnibuses are driven by a somewhat novel arrangement of internal combustion engine and electricity. The primary motive power is derived from a petrol or internal combustion engine, the usual fly-wheel

of which is replaced by a dynamo mounted on the crank shaft, which latter takes both the place and performs the functions of the fly-wheel, and at the same time charges a storage battery or accumulator.

The advantage of this arrangement is that the internal combustion engine need only be sufficiently powerful to propel the vehicle on a level surface at the highest speed it is intended to run at. The energy stored in the accumulator can be utilized for driving through an electric motor when any extra power is required. The consumption of petrol is said to be reduced about 50 per cent.

The vehicle can be started by means of the electric motor, whenever there is a sufficient storage of electricity in the accumulator, and the internal combustion engine can then be brought into use.

This type of omnibus is said to have been tried in France with considerable success.

ELECTRIC OMNIBUSES

The advantages and disadvantages of electricity as a means of propulsion for road vehicles have been already briefly enumerated. As a power, the electric motor is incontestably a most suitable medium for automobile work, by reason of its being practically perfectly safe, its capacity for direct application, its high ratio of efficiency, and the facility with which it can be controlled. Not only does the electric motor automatically control the consumption of energy, both with light and heavy loads, in proportion to the power delivered, but it will also work, should occasion arise, with an overload of several hundred per cent. for brief periods of time, without any appreciable inconvenience. Other by no means inconsiderable advantages are the practically total absence of smell, heat, and vibration, and the capacity for running equally well in either direction.

These advantages, however, as well as the counterbalancing disadvantages of excessive weight of storage batteries, the limited amount of miles that can be run on each charge, loss of time recharging, and cost of renewing batteries, etc., have been, as above mentioned, already gone into as fully as the space at command will allow.

EXAMPLES OF ELECTRIC OMNIBUSES

The City and Suburban Electric Carriage Company Electric Omnibuses

The City and Suburban Electric Carriage Company, of York Street, Westminster, S.W., are builders of a number of different patterns of electric omnibuses. One pattern has a capacity to seat eight inside and seven outside passengers, or fifteen persons in all, including the driver. The other omnibuses have capacities for six inside and seven outside, or thirteen passengers; eight inside and two outside, or ten passengers; and six inside and two outside, or eight passengers. The two first-mentioned vehicles have also accommodation for a certain amount of luggage on the roof.

The driving mechanism of these omnibuses is practically similar to that of the electric hansom built by the same firm, which has been already described. The maximum mileage of all the omnibuses is 25 miles on one charge, and the maximum speed in each instance is 10 miles an hour. The sixteen-seated electric omnibus, as also that adapted to seat six persons inside and seven outside, are fitted with 3-inch solid indiarubber tyres, and the other two omnibuses with similar tyres 2½-inches diameter.

The Vehicle Equipment Company's Electric Omnibuses

As another example of an electric omnibus may be cited that of the Vehicle Equipment Company, of New York, the sole agents for whom in this country are the Anglo-American Motor Car Company, Limited, of Queen Victoria Street, London, E.C.

A type of electric omnibus built by the above company for hotel service has a carrying capacity of about 9 cwts., a maximum speed of 12 miles an hour, and a maximum mileage of 35 miles on one charge.

The arrangement of the running gear of this vehicle is shown, in side elevation, in the diagrammatical view, Fig. 59, in which *a* indicates the body frame, *b* the storage battery cradle, *c* one of the electric motors, *d* the pedestals supporting the axles, and *e* the top of the driver's seat.

The body frame *a* being of steel and of ample strength, relieves the body of the vehicle of any strain or tendency to buckle, and also affords a substantial support for suspending the battery, so as to leave the interior of the vehicle absolutely clear.

The running gear is of a "pedestal" type, patented by the makers, and consists of a single steel casting secured to the steel body frame *a*. The axles are supported in the jaws of the pedestals *d*, in such a manner as to have perfect freedom of motion in a vertical direction, through a sufficient range to permit full play of the springs.

Each of the rear, or driving, wheels of the vehicle is operated

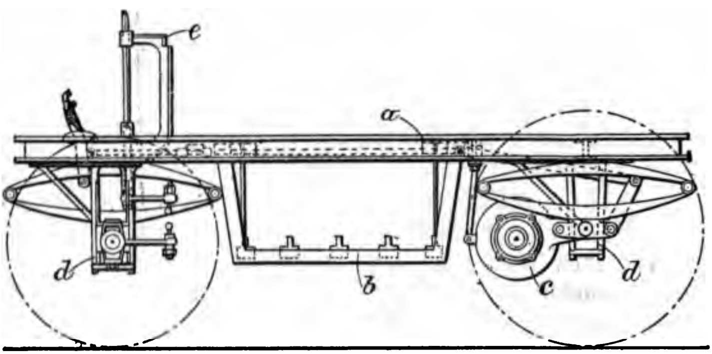

Fig. 59.—The Vehicle Equipment Company electric omnibus. Diagram of running gear.

independently by an electric motor, *c*, and the controller is located beneath the driver's seat, and is operated by direct connection with a hand lever. Four different speeds ahead, and two speeds in a reverse direction, can be effected by means of the controller. Steering is on the Ackermann principle, and the arrangement is strong and reliable. On the heavier class of vehicle it is operated by a steering wheel, and on the lighter ones by means of a steering bar, or lever.

The storage battery is made in sectional trays, adapted to slide into the battery cradle *b*, which latter is so constructed that the trays can be drawn out on whichever side of the vehicle may be found to be the most convenient. An important advantage possessed by this arrangement of battery cradle is that the batteries are thus made accessible in a few minutes without

necessitating the use of a hydraulic lift. The storage battery is charged at 100 to 115 volts, direct current, and at an amperage of from 30 to 60.

The wheels are of the artillery pattern, wooden spokes and felloes with metal hubs, and are shod with solid indiarubber tyres, which latter are, according to the makers, found preferable in practical working owing to the avoidance of difficulties with punctures, etc., whilst quiet and easy riding is ensured by mounting the body frame *a* on extra long and flexible springs. Ample brake power is provided, and the vehicle is fitted with electric side-lights, etc.

CHAPTER VI

LIGHT GOODS VANS

General Observations—Light Petrol Vans—Examples of Light Petrol Vans—Light Steam Vans—Light Electric Vans—Examples of Light Electric Vans.

GENERAL OBSERVATIONS

SELF-PROPELLED vehicles of this class comprise, as has been already mentioned, all those suitable for tradesmen for the quick delivery of goods, and adapted for loads up to about 20 or 30 cwts. Internal combustion engines, steam engines, and electricity are all three found to be suitable sources of power for the propulsion of light goods vans, and each seems to possess some special qualifications for the purpose.

As regards the advantages to be derived from the use of motor vehicles for the work in question, they have been already briefly specified in the introduction to these articles, and need not therefore be further referred to. The cost of running and maintenance is dealt with in a separate chapter.

LIGHT PETROL VANS

Internal combustion engines offer many special advantages for the propulsion of light delivery vans, and vehicles of this type are now built in a great variety of patterns and of different capacities by a very large number of firms; in fact, by most of the makers of motor vehicles propelled by means of internal combustion engines. The systems of driving employed are consequently the same as those used in the pleasure vehicles made by the same firms, which are now so well known as to need no description here. The bodies of the vans are, of course, adapted to meet the requirements

of various businesses, and are suited for the quick delivery of all manner of goods.

The number of light petrol vans is so large that it is impossible to give here more than a very brief description of a few representative vehicles, nor, indeed, is more necessary, inasmuch as they are, as has been already mentioned, driven in practically the same manner as the pleasure vehicles built by the same makers, and only differ in some minor details of construction.

EXAMPLES OF LIGHT PETROL VANS

Horsfall and Bickham Light Petrol Vans

Light delivery vans are built by Messrs. Horsfall and Bickham, of Manchester, capable of dealing with loads up to 10 cwts., and providing accommodation for two persons, with driver.

The source of power is an internal combustion or hydrocarbon engine having two cylinders each $4\frac{1}{8}$ inches in diameter, by $4\frac{3}{8}$ inches stroke, giving 10-horse-power at a normal speed of 800 revolutions per minute, and capable of developing 11·5 brake horse-power when run at an accelerated speed. The heads and cylinders are cast integral, and the valve gear is of the enclosed pattern, and an improved type of governor acting on the throttle valve is provided. Lubrication is on the splash system. The carburettor is of the constant level float-feed type, and the electric ignition is effected by means of accumulators and a high-tension coil.

The vehicle is fitted with change-speed gear of the Panhard type, in which a sleeve is mounted on the transmission shaft, so as to be free to move laterally thereon, whilst at the same time it is forced to rotate therewith by a key or feather. This sleeve carries three toothed or spur wheels which gear or mesh with the one or other of a set of toothed or spur wheels mounted upon another or second transmission shaft placed parallel with the first transmission shaft. The mechanism is so arranged that no change from one rate of speed to another can be effected until the toothed wheels are completely out of gear and the driving and intermediate shafts are disconnected. There are three forward speeds of 4, 8, and 12 miles an hour, and a reverse, and the highest speed

is direct driven, manipulation of the sliding sleeve being effected by means of a lever placed within convenient reach of the driver. The axle is fitted with Cardan, or universal joints, the wheels being of the artillery pattern, both front and rear being 30 inches diameter, and fitted with solid indiarubber tyres. Both the road wheels and the differential gearing are provided with ball bearings.

The steering is operated by an inclined wheel, through a worm and worm wheel, and is irreversible, and there are three double-acting brakes, one an external expanding hand brake on rear wheels, besides a powerful foot brake acting on the differential shaft.

In addition to the regulation that can be effected by means of the change-speed gear and brakes, the supply of mixture to the engine can be effectively controlled through a throttle valve operated by a lever.

Benz Light Petrol Vans

Light delivery vans with carrying capacities of 2 cwts., 3 cwts., 15 cwts., and about 20 cwts. respectively, are built by Messrs. Benz and Co., of Mannheim, Germany, the sole agents for whom in this country are Messrs. Hewetson, Limited, London. As is well known to those interested in the subject, the first patent for a vehicle propelled by an internal combustion engine was granted to Messrs. Benz in January, 1886, for a spirit motor car made in 1885, and being the result of many years' study of the subject by Mr. Charles Benz. The Benz motor has proved itself a very efficient one, and, besides being used in their own vans and other motor vehicles, is also extensively employed as a prime mover in those of other manufacturers.

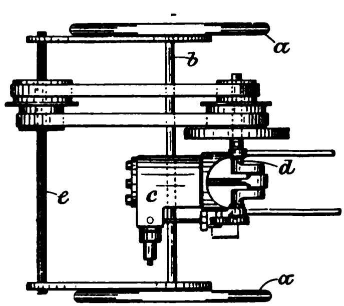

Fig. 60.—Benz light petrol van. Diagram of running gear.

The lightest types of Benz delivery vans have the following approximate dimensions: length, $7\frac{1}{2}$ ft.; width, $6\frac{1}{2}$ ft.; and height,

$6\frac{3}{4}$ ft. The approximate weight is 8 cwts. 2 qrs. The engines are 3-horse-power and 3·5-horse-power, and there are three forward speeds and a reverse. The wheels are bicycle pattern in one type and artillery pattern in the other, and are fitted with solid india-rubber tyres, rubber brake blocks, and Salter's springs. Chain-driving is used, Brampton-Hewetson chains being employed, and the highest speed is 12 miles an hour. These vans are capable of climbing a gradient of 1 in 5, or 20 per cent., with facility. The 15 cwts. capacity van is fitted with a 6 to 8-horse-power engine.

Fig. 60 is a diagrammatical view, showing the arrangement of running gear of a Benz vehicle, in which *a* indicates the wheels, *b* the axle, *c* the engine, *d* the crank shaft, and *e* the intermediate shaft.

In the single cycle Benz motor, which is a very constant and powerful motor of its class, the gas is compressed in a clearance at one end of the cylinder during the stroke of the piston in a forward direction, electric ignition being provided at the side of the cylinder. The air that has filled the cylinder at the other side of the piston is then forced into a reservoir through a port or aperture governed by a slide-valve, which closes the port or aperture at the end of the stroke, and the cylinder end is opened to the atmosphere, so as to allow of a fresh supply of air being sucked in during the reverse stroke of the piston. An exhaust valve is also operated during this stroke to admit of the escape of the burnt or waste gas, and the opening of another valve at about half-stroke permits the charge of compressed air to pass from the reservoir into the cylinder, through which it rushes and passes out of the exhaust, thus completely sweeping out all the burnt or waste gas in its passage. The above-mentioned valves are then automatically closed, the fresh air still remaining in the cylinder is compressed, the petroleum vapour is injected through a valve which is automatically actuated by a lever, and the explosive mixture thus formed is fired or ignited at the commencement of the next stroke.

The objection to this type of motor is that the operation entails the provision of a considerable number of parts, and consequently is somewhat complicated in construction and rather heavy. The Benz motor, arranged to work on the Otto cycle, is far simpler in construction, and has a cylinder open at one

extremity and but two pipes—that is to say, an admission pipe and an exhaust pipe. The complications of slide and valve gear are also dispensed with.

Milnes-Daimler Light Petrol Vans

The Milnes-Daimler Company, Limited, are builders of several types of light delivery petrol vans, a useful size being that adapted to carry loads up to half a ton, and having a 6-horse-power engine. The company also build a van to carry loads up to one ton, and fitted with a 7-horse-power engine.

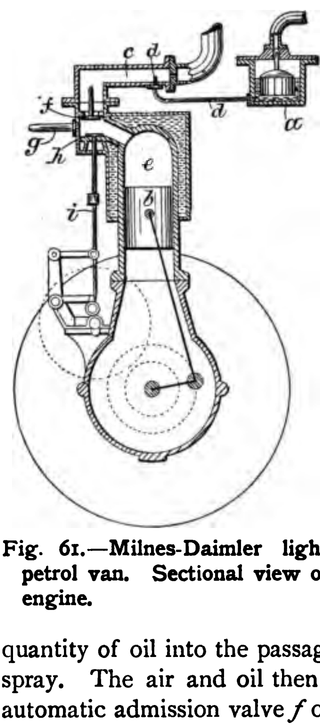

Fig. 61.—Milnes-Daimler light petrol van. Sectional view of engine.

The most important feature in these vans is the engine or motor, which is of the well-known Daimler type, extensively used by many other builders of motor vehicles. The construction and operation of this type of motor will be understood by reference to the sectional diagrammatical view, Fig. 61.

A small tank, *a*, shown at the right-hand top corner, is fed with oil spirit, the level of the latter being regulated by the float valve shown, through a suitable check valve. When the piston *b* makes its stroke in an outward direction air enters the way or passage *c*, and, by flowing over the end of the oil-pipe *d*, draws a small quantity of oil into the passage *c* by induction in the form of fine spray. The air and oil then pass into the cylinder *e* through the automatic admission valve *f* on the left hand.

On the return stroke of the piston *b* the automatic valve *f* is closed, and the charge is compressed into the ignition tube *g*. The exhaust passes out through the valve *h*, which is situated below the admission valve, and is raised by the rod *i*.

The governing of the engine is effected by an arrangement for keeping the exhaust valve *h* open and allowing the burnt or waste

gases to return to the cylinder, and so destroying the partial vacuum in the latter, and preventing the admission valve *f* from opening.

Delahay Light Petrol Vans

A typical example of a light van by these makers is one adapted to carry loads up to 12 cwts. This vehicle has a horizontal 10-horse-power engine, and is fitted with single belt transmission from the engine shaft to the intermediate shaft, having a patent arrangement for preventing slip. There are three speeds in a forward direction and a reverse. The maximum speed is 12 miles an hour. The operation of a belt transmission gives rise to less friction than chain or wheel transmission, and is in every way preferable, provided, of course, that excessive slip can be avoided.

Chenard Light Petrol Vans

Amongst other patterns, a very useful little light delivery van is built by these makers, which is remarkably silent in running, and can be steered in heavy traffic with great ease. It is also especially noticeable by reason of its very low oil consumption, and took a high place in the consumption trials held in France last year.

Gardner-Serpollet Light Petrol Vans

Light vans adapted for delivering parcels, and capable of carrying loads up to 4 cwts., are made by the Gardner-Serpollet Company. This little van, which is built in one pattern only, weighs, complete with body, about 9 cwts. It is lightly but strongly constructed, with a tubular frame, and is fitted with a double-cylinder vertical type of petrol engine of 7-horse-power, which is located in front beneath the bonnet. There are three speeds and a reverse, the maximum speed being 28 miles an hour.

The body of this van can be removed when desired, and seats fitted so as to adapt it for use as a pleasure or passenger vehicle. It is handy, easily steered, and can be managed with facility by any one after a little preliminary practice.

Other Light Petrol Vans

Amongst the numerous other light petrol vans which space does not admit of even briefly describing, mention may be made of those of Hagen, the Hozier Company, Gillet, Forest & Co., S. F. Edge, Limited (the "Gladiator"), and Farman & Co. (the "Argyll").

LIGHT STEAM VANS

Thornycroft Light Steam Vans

Light delivery vans propelled by steam power are made by a number of different makers, a typical example being the steam van shown in Fig. 62, which view is a direct reproduction of a

Fig. 62.—Thornycroft light steam van.

photograph of one of these vehicles built by the Thornycroft Steam Waggon Company, Limited, for the Middlesex Hospital Laundry, Hendon, which vehicle has been running successfully for some time, and is adapted to carry loads up to one ton.

Light steam delivery vans of a practically similar form of construction have been also supplied to the Mid-Sussex Steam Laundry Company, Limited, Lindfield, Sussex, and several other concerns.

The over-all dimensions of this type of vehicle are approximately: length, 15 ft. 6 ins.; width, 6 ft. 6 ins.; height, 10 ft. The approximate inside dimensions are: length, 8 ft. 3 ins.; width on floor, 4 ft. 3 ins.; width over raves, 5 ft. 3 in.; height, 5 ft. 8 ins. The body is of wood, canvas-covered and painted, the wheels are of the artillery pattern, with metal naves and wooden spokes and felloes.

The boiler, engine, and the rest of the driving mechanism is practically of the same pattern as that of the Thornycroft steam omnibuses that have been already described. The vehicle is capable, as already mentioned, of carrying loads up to 20 cwts., and the maximum speed is 12 miles an hour.

Other Light Steam Vans

There are many other makers of light steam vans. Those of Clarkson, Limited, are constructed on the same principle as their omnibuses described and illustrated on pp. 79 to 103. The Gillett Motor Company, Gillet, Forest and Company, and the White Steam Car Company are makers of excellent light vans propelled by steam power.

LIGHT ELECTRIC VANS

Electricity is a power much used in the United States, and, it is averred, with very great success, for the propulsion of light goods vans. As has been already mentioned, the use of electricity for lighting and power is more general in that country than it is here, consequently it is not surprising that this source of power should have become a favourite one for both light and heavy motor vehicles. Moreover, it must be acknowledged that electricity already possesses many advantageous features for the work, whilst it is not improbable that in the near future improvements in storage batteries, and the further development of the application of electricity generally in this direction, may place it in the premier position.

Light delivery vans propelled by electric power are built by a considerable number of firms abroad, and a few makers in this country, the following being fair examples of the class :—

EXAMPLES OF LIGHT ELECTRIC VANS

The Vehicle Equipment Company Light Electric Vans

This company, whose sole agents here, as has been already mentioned with respect to electric omnibuses, are the Anglo-American Motor Car Company, Limited, are builders of several patterns and sizes of light delivery electric vans, one of which, having a capacity of about 8 cwts., is illustrated in Fig. 63. The maximum

Fig. 63.—The Vehicle Equipment Company light 8-cwt. electric van.

speed per hour of this vehicle is 12 miles, and the radius on one charge is 35 miles. The running gear is practically similar to that described (and shown in Fig. 59) with reference to their electric omnibuses, which gear is, indeed, common to all their vehicles, and consequently needs no further description.

The International Motor Car Company Light Electric Vans

The above company, whose works are at Indianapolis, U.S.A., and whose agents in this country are the Locomobile Company of Great Britain, build several sizes of light delivery electric vans, a typical example being that known as the "Waverly," which is adapted to carry up to 15 cwts. of goods, and capable of running 40 miles with full load on a single charge. The storage battery or accumulator consists of a battery of 40 Sperry cells, with a capacity of 150 ampère-hours, and is also in this case suspended beneath the van, thus securing the advantage of the discharged cells being easily removed and replaced by a charged set. Each of the rear wheels is driven by a separate electric motor of 3-horse-power, through double helical gear, with staggered teeth, a type which both makes a silent drive and is also free from back-lash. The battery being carried beneath the van body, the entire platform is free to receive goods, the space available being 5 ft. 2 ins. by 3 ft. by 4 ft. 2 ins. in height.

The over-all length of the body is 8 ft. 3 ins., and the greatest height from the ground 6 ft. 3 ins. The wheel base is 6 ft. 8 ins. by 4 ft. 6 ins., and the wheels are of wood, each 30 ins. diameter, shod with $3\frac{1}{2}$-in. wide detachable pneumatic tyres.

The change speed is effected by various controller combinations, the controller being placed at the left-hand side of the driver's seat, and three forward speeds of from 5 to 12 miles an hour and a reverse are arranged for, as well as an electric brake position. A powerful band-brake, operated by a foot lever, is also provided. The steering is of the lever type. The condition of the accumulator can be ascertained by the driver from a Keystone combined volt and ampère meter, attached to the sloping foot-board, which can be lighted up at night.

Although the electric motors are nominally 3-horse-power each, they are so designed as to be capable of working up to a temporary overload of 100 per cent. when required, without injury.

The City and Suburban Electric Carriage Company Light Electric Vans

Amongst the light delivery electric vans built by the above firm is one adapted for loads up to half a ton. The maximum speed of this vehicle is 12 miles an hour, and the maximum mileage on one charge of current, with full load, is 35 miles. The wheels are wood, of artillery pattern, and shod with 3-in. diameter solid indiarubber tyres.

The details of construction of the running gear and the general arrangement of the mechanism of the above van are substantially the same as in the case of the hansom cab built by this company, which has been previously described and illustrated on pp. 74 and 75.

Oppermann Light Electric Vans

One pattern of the light delivery vans driven by electricity built by the Carl Oppermann Electric Carriage Company, Limited, London, is shown in Fig. 64.

The van is capable of running a distance of 50 miles with a load of 15 cwt. on one charge. The frame is constructed of cold-pressed steel; the wheels are of the artillery type, with ash felloes and oak spokes, mounted on steel hubs with roller bearings, and solid indiarubber tyres 3 in. wide and 32 ins. diameter. The axles are of the best hammered steel, the front one being fitted with Ackerman steering and ball-bearing sockets, and either a hand wheel or lever. The frame (a perspective view of which is shown in Fig. 64) is quite complete and self-contained.

The electric motor employed is of the enclosed type, 5-horse-power nominal, capable of withstanding considerable overloads, and fitted with self-acting lubricators. Power is transmitted direct from the motor to the rear axle by means of an improved arrangement of worm gearing enclosed in a dust-proof casing.

The accumulator consists of 44 A.B.C. cells, each fitted in an ebonite box, and these are in turn enclosed in strong wooden cases for convenience of handling, and divided so as to enable the available space beneath the body to be fully utilized. The cells are composed of a number of leaden plates or grids (five positive

and six negative) pasted or filled with oxides of lead and some suitable binding material, so as to render the entire mass very solid and firm, and to form together what is termed the active

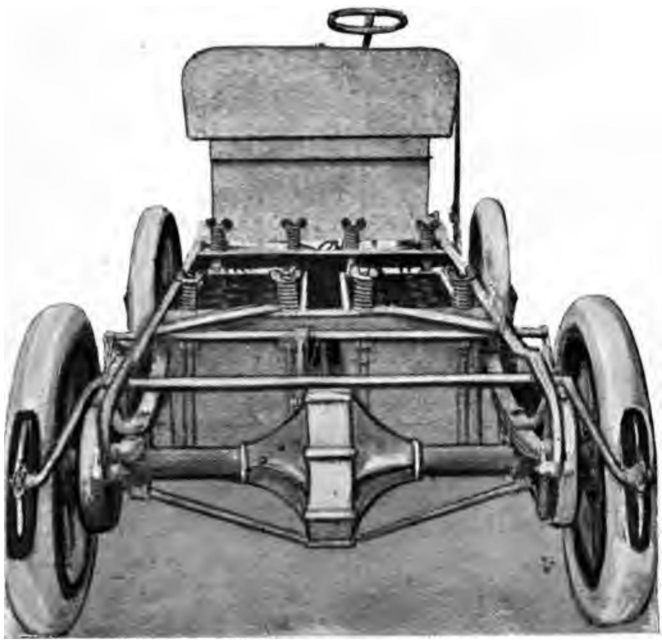

Fig. 64.—Oppermann light electric van. Rear view of frame.

material. The plates are separated by sheets of perforated ebonite, and are secured together by ebonite bolts before being placed in the ebonite boxes, in which they are immersed in dilute sulphuric acid. The weight of the battery is 10 cwts. It gives E.M.F. of 83 volts, and has a capacity of 150 ampère-hours.

The Maxwerke Electric Vans

In the Maxwerke electric vans, which are built by Messrs. Harff and Schwarz, of Cologne, the electric motor is carried on springs at the centre of gravity of the vehicle, and drives the rear axle direct through a toothed wheel cast on the hub. The

storage battery is in front, and the different speeds are secured by acting on the motor. The lever controlling the speeds, when moved to its extreme limit of travel, operates the brakes. This latter arrangement prevents the brakes from being applied whilst the motor is running.

Other Light Electric Vans

Amongst other light electric vans which limit of space prevents being described, mention may be made of those of Messrs. Shippley Brothers, Limited (the Still system), constructed to carry 10 cwts., 1 ton, 2 tons, etc., and the Columbia electric vans.

CHAPTER VII

HEAVY-FREIGHT VEHICLES

General Observations—Heavy-freight Steam Vehicles—Wheels—Driving — Steering — Transmission — Boiler — Engine — Power Required—Results obtained with Heavy-freight Steam Vehicles—Examples of Heavy-freight Steam Vehicles.

GENERAL OBSERVATIONS

HEAVY-FREIGHT vehicles will undoubtedly form in a few years the most important branch of the self-propelled vehicle industry, as in this direction the possibilities of mechanically propelled road vehicles are admittedly unbounded. It is characteristic of the different temperaments of the French, English, American, and German nations, that whilst the first have mainly confined themselves, and it must be admitted with considerable success, to the perfection of motor vehicles for pleasure purposes, the three latter have, on the other hand, largely concerned themselves with those of a utilitarian description. The present more or less ephemeral boom in pleasure vehicles amongst the idle and moneyed classes in this and other countries has naturally turned considerable attention in that direction, and the phenomenal demand that has arisen for pleasure vehicles has given birth to a number of new undertakings specially devoted to their manufacture, or practically so. Many of our well-known and old-established firms of engineers, and also a number of more recently established firms, however, have devoted themselves to the serious and important task of the perfection of the heavy-freight vehicle, and that, too, with acknowledged success; and when the pleasure-seeking class tire of the doubtful amusement of tearing aimlessly about the roads, with the usual accompaniment of clouds of dust, stinks, and noise, to their own and other people's discomfort, and to the danger of the public, and the

inevitable slump in fast pleasure vehicles arrives, the first-mentioned concerns will likewise turn their attention to the construction of vehicles of a more solid and useful description.

Heavy-freight vehicles are built with steam, electricity, and internal combustion engines as propelling powers, and each of these systems possesses certain distinct advantages, the two first being, however, up to the present the most practically successful.

In this country steam-driven freight vehicles for heavy loads are most favoured, but in the United States, where electricity is more extensively used as a motive power, this latter is also employed with considerable success.

In France, where the internal combustion engine has practically displaced the steam engine, the former has naturally been more extensively applied to heavy-freight vehicles, and also with very considerable success. At one time, indeed, it was generally supposed that the heaviest load capable of being dealt with by the internal combustion engine was about one ton, but recent improvements have rendered it possible to carry with ease considerably heavier loads, waggons being built with capacities up to five tons and over.

The results obtained with steam waggons in Great Britain and the United States have been exceptionally good.

HEAVY-FREIGHT STEAM VEHICLES

The following extracts from a paper by Mr. Arthur Herschmann, read before the American Society of Mechanical Engineers, in which he gives his opinion on the best form of steam waggon, as deduced from the results of a two years' investigation made by him in the interests of the Adams Express Company, of New York, to which concern he acted as mechanical engineer, will be of interest.

Wheels

As regards wheels, Mr. Herschmann is of opinion that no form of indiarubber tyre will give satisfaction on a commercial waggon intended to carry a net load of, say, one ton or more, being not only expensive, but giving poor satisfaction under the combined action of great weight and speed. Well-constructed

springs of ample proportion, he thinks, are the only means of lessening the shock to which a waggon wheel is subjected. In the case of dished or cored wheels, which he considers the best adapted for heavy work, a steel tyre is indispensable, since it binds the wheel together and prevents the spokes from being torn out when striking an outer obstruction. As regards the width of wheels, he thinks that the width of the tyres in inches should be at least twice the number of gross tons carried, where small waggons are concerned, say, of a capacity of two tons net load; this coefficient of two to decrease in the case of very heavy waggons to one and even under. Small driving wheels are used on motor waggons owing to the difficulty of designing large wheels which will stand such severe strains as motor waggon wheels are subjected to. In this case, the spokes of the wheel not only support the load, as in a horse-drawn vehicle, but they are more or less affected by the action of the driving power, and, moreover, there is also a tendency to twist them. With the ideal waggon the power should be applied directly where the wheel touches the ground. Usually the drive is into a spur wheel, or chain wheel, concentric with the wheel, but, of course, of a smaller diameter, and such an arrangement makes it desirable that the wheel shall be also small. Another reason making small wheels desirable lies in the requirements of the waggon, and the working of a high-speed motor. In other respects, Mr. Herschmann considers that a large driving wheel, say, of 4 feet diameter, would answer much better than a 3-foot wheel, such as has been almost exclusively applied to steam waggons. Not only does a 4-foot wheel allow of a more powerful starting torque, but it also saves the driving gear by not sinking so deep as a small wheel when passing over a depression in the road surface.

Driving

With respect to front driving, Mr. Herschmann says that any advantage which it possesses as regards better steering is more than outbalanced by the disadvantages introduced in connection with awkward location of the machinery. He thinks that if a practical arrangement for driving through all four wheels could be introduced, it would prove an excellent feature in a waggon.

Steering

Referring to the two main systems of steering, viz. steering with a fifth wheel, and steering with pivoted axle ends, Mr. Herschmann considers that the first-mentioned arrangement is theoretically the best adapted for heavy work, inasmuch as it leaves the waggon axle unbroken. In reality, however, this system cannot be as satisfactorily applied as steering with pivoted axle ends. To effect the steering of heavy waggons, spur-gearing of suitable purchase has to be used, or a worm and worm-wheel device. The latter arrangement he considers, however, to be less desirable than steering by spur gearing, since it locks the gear, and besides causes a severer strain on the waggon in case the front wheels strike an obstruction. In rounding a curve, the inner wheels necessarily describe a smaller circle than the outer wheels. To make this practicable, the steering device has to be correctly designed, and the two driving wheels have either to be driven by independent motors or have to be linked together by means of a compensating gear, or, as it is often called, "jack-in-the-box." It will be found that in a heavy waggon, particularly one with dished wheels, this driving and the arrangement of the compensating gear are rather troublesome, and that there is still great scope for improvement in this connection.

Transmission

The transmission gear, forming the link between the rear wheels and the engine, which is almost invariably placed in front of the driving wheels, can, says Mr. Herschmann, only be reliably effected by means of accurate spur wheels, immersed in an oil bath. With a steam waggon it is not necessary to use any kind of a clutch whilst running, seeing that the steam engine is a very flexible prime mover. Nevertheless, a speed reduction gear which can be best provided by means of two sets of spur wheels of varying diameters, one set stationary, the other movable axially on a square shaft, forms a desirable adjunct to the mechanism, and can be shifted when the waggon is at rest so as to increase its traction power, and enable it to negotiate any special hill, or extricate the waggon from a bad position. And

it cannot be denied that for many years to come, both in America and in this country, greasy and hilly roads, or deep snow, will be the greatest difficulties to contend with. Attempting on a damp day to take a load of four tons up an incline of about 1 in 20, covered with Belgian blocks, trouble was experienced through the drivers racing. The engine was geared 1 to 14, and the wheels were 3 feet in diameter. In Mr. Herschmann's opinion, larger and heavier driving wheels and a much lower gear would have taken the waggon up. With the slightest turn of the valve the engine, without difficulty, started, and, on account of the poor adhesion and the light machinery, ran away before the inertia of the heavy waggon was overcome.

Boiler

Coming to the boiler and engine, this authority considers that the desiderata for a suitable boiler for a motor waggon are that it should be of the greatest safety, of small proportions, quick steaming and economic, and in addition it should be of the simplest possible construction, and free from joints likely to work loose by jarring on the road. Pipe boilers, whilst perhaps a little safer than shell boilers, carrying little water, are for the same reason undesirable for the varying demands made of a waggon boiler. Other objections to small-calibre pipes are that they are necessarily exposed to intense heat, and are liable to burn, and without a large dry steam tank or dome they will make wet steam. A shell boiler, on the other hand, can be made of ample proportions, and, if well constructed and watched during its use, should give no apprehensions as to its safety, and the water level can be more evenly maintained, which is a point of some importance. A superheating device is an all-round advantage, provided that it is correctly applied to the boiler.

In addition to the engine feed pump, there should always be a second steam-driven pump, instead of an injector, which latter, when of small proportions, has not yet been made to give satisfaction on a waggon, in practical working.

For firing coal and coke are preferable to oil for fuel, being besides cheaper in use. It is difficult to keep oil burners in good trim in all kinds of weather, and they will "roar" and occasionally give trouble and make smoke. Solid fuel can be conveniently

stowed away around the boiler, which latter is generally fixed in front of the waggon, where the fuel acts as a compressible safeguard to the boiler in case of a bad collision. In using a shell boiler it is found convenient to fire through the boiler top, after the fashion of the De Dion boiler.

Difficulties to be contended with in steam waggons are that they will occasionally show a little steam, and during a sharp frost it is difficult to prevent a pipe from being frozen up. Blowing off is largely caused by neglect of the driver. By the use of a condenser there would be practically no visible exhaust in all weathers, but Mr. Herschmann does not favour the use of a condenser, owing to the chance of leaky pipes, and the difficulties of running. Difficulties in connection with smoke have been already overcome.

Engine

With regard to the engine, Mr. Herschmann says that in all cases a light, well-designed, quick-revolution, compound engine will answer the purpose, if it is fitted with reversing gear and means to admit high-pressure steam to the low-pressure cylinder. The cylinder ratio should be larger than in stationary practice, seeing that the pressure used is higher, and that a large low-pressure cylinder means a powerful starting movement under live steam. Especial care should be taken to connect the engine to the frame in an efficient manner. A fly-wheel is sometimes fitted, in which case it is used as a brake wheel; he considers it, however, to be unnecessary.

Generally, says Mr. Herschmann, it is to be observed that most of the waggons constructed are by far too light to stand the severe strain of their work; the cost of actual propulsion per gross ton is by no means so important an item in the case of a steam waggon as it is in that of an electric vehicle, and provision for durable construction can therefore be amply provided for, and a heavy vehicle is just as easy to bring to a standstill as a light one, in fact easier, since it may be fitted with quicker acting brakes, which, on account of their severe action, could not be fitted to one of light construction.

Power required

For a waggon capable of carrying a load of 3 tons and able to mount an incline of 1 in 10 at 2 miles per hour, the machinery should be capable of producing, when going uphill, a total of about 20-horse-power.

Such a waggon should have a boiler with about 100 feet of heating surface exposed to hot gases. Its speed should not be above 6 miles per hour to operate economically. The brakes should enable the driver to stop the waggon when descending the above-mentioned incline in a distance of about 10 yards.

The table on page 168 gives the results obtained with a number of steam heavy-freight vehicles.

EXAMPLES OF HEAVY-FREIGHT STEAM VEHICLES

Mann Heavy-freight Steam Vehicles

Several types of heavy-freight motor vehicles are manufactured by Mann's Patent Steam Cart and Waggon Company, Limited, at their works at Hunslet, near Leeds. As will be seen from the illustrations, Mr. Mann has utilized his previous experience in traction engine work, adopting what he esteems to be the most valuable features of a traction engine, and has designed a type of motor vehicle of an entirely novel form of construction.

As originally designed, the Mann steam lorry consisted of two parts, the platform forming a separate vehicle or trailer on its own wheels, which were of the same diameter as the engine wheels, the space between them being just sufficient to allow of their coming outside the latter (as shown in Fig. 65), and being connected to them by bolts so that they became driven wheels instead of trailers. The object of this arrangement was to comply with the old motor-car restrictions to 3 tons weight, the lorry weighing over 4 tons without infringing the regulations.

The following are the approximate over-all dimensions and weight of this engine and lorry: length, 18 ft. 6 ins.; width, 6 ft. 4 ins. The body of the lorry, 12 ft. in length, by 6 ft. 4 ins.

RESULTS OBTAINED WITH HEAVY-FREIGHT STEAM VEHICLES.

Vehicle.	Weight and loads—tons. Tare.	Fuel and water.	Net.	Gross.	Ratio, net tare.	Speed in miles per hour.	Maximum gradient climbed.	Engine cylinders and stroke.	Fuel.	Gauge with pressure in pounds. Square inches.	Heating surface. Square feet.	Grate area. Square feet.	Evaporation in pounds per pound of fuel.	Per cent. of efficiency of boiler.	Pounds of water per gross ton-mile.	Pounds of fuel per gross ton-mile.
Leyland	2·9	0·35	4·1	7·35	1·41	5·7	1·7	3 ins. and 5 ins. by 6 ins.	Oil	200	110	—	—	—	—	0·6
,, (Liverpool, 1899) ...	2·85	0·35	4·44	7·64	—	6·17	—	2·75 ins. and 5 ins. by 6 ins.	Oil	167	110	—	—	—	—	—
Thornycroft (Birmingham, 1898)	—	—	3·88	6·88	—	6·20	—	4 ins. and 7 ins. by 5 ins.	Coal	—	—	—	—	—	—	2·79
Thornycroft (Richmond, 1899)	—	—	3·95	6·95	—	5·45	—	4 ins. and 7 ins. by 5 ins.	Coal	—	—	—	—	—	—	1·38
Thornycroft (Uxbridge, 1899)	2·90	0·56	3·4	6·85	1·13	5·5–7	1·6	4 ins. and 7 ins. by 5 ins.	Coal	175	65	2·5	6·9	53·3	9·8	1·42
,, (Liverpool, 1899)	3·0	0·51	3·73	7·24	—	5·94	—	4 ins. and 7 ins. by 5 ins.	Coal	147	83	—	8·3	—	8·3	1·0
Liquid Fuel Co. (Liverpool, 1898)	2·39	0·35	2·20	4·94	—	8·29	—	3 ins. and 6 ins. by 5 ins.	Oil	207	80	—	—	—	—	—
Clarkson (Liverpool, 1899)	3·00	0·33	3·35	6·68	—	5·59	—	2·75 ins. and 6 ins. by 4 ins.	Oil	193	80	—	—	—	—	—
De Dion (France, 1898) ...	4·72	0·63	3·25	8·60	—	6·33	—	4 ins. and 7·75 ins. by 6 ins.	Coke	200	64	1·95	—	—	—	—
Bayly (Liverpool, 1899) ...	2·97	0·49	3·67	7·13	—	5·54	—	4 ins. and 7 ins. by 5 ins.	Coke	174	70	—	—	—	—	—
,, (Richmond, 1899) ...	—	—	2·63	6·63	—	5·22	—	4 ins. and 6·5 ins. by 5·5 ins.	Coke	—	—	—	—	—	—	0·95
Lancashire Co. (Birmingham, 1898)	2·93	0·48	3·44	6·54	—	6·48	—	3 ins. and 5 ins. by 6 ins.	Oil	—	—	—	—	—	—	0·59

in width. The net weight of the engine, 3 tons; the approximate net weight of lorry, 1 ton 5 cwts. The lorry wheels are of iron, 3 ft. 6 ins. in diameter by 5 ins. in width, and connected by three driving pins or bolts to the engine road wheels, which are of the same diameter and width. The two thus come close together as shown, with the lorry wheels on the outside, and the width of the driving-wheel tyres are thus 10 ins. on each side of the engine.

The frame of the lorry is constructed of channel steel, firmly braced together by flanged steel ends, and covered by a wood flooring. The body is balanced, and can be tilted in order to render the engine more readily accessible for adjustment and examination.

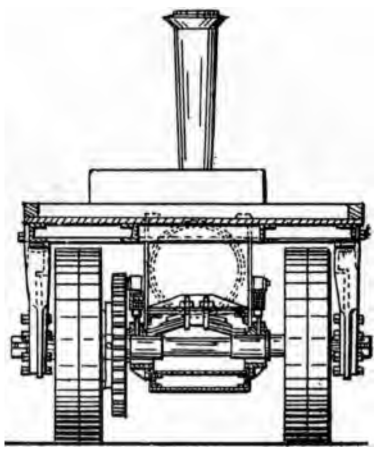

Fig. 65.—Mann heavy-freight steam vehicles. Original pattern of lorry.

Figs. 66 and 67 show respectively the most recent pattern of non-tipping and tipping waggons constructed, each of 5 ton tare weight, to take advantage of the recent concession.

The engine used in the Mann heavy-freight vehicles is of the horizontal compound type, the high-pressure cylinder being 4 ins. in diameter, and the low-pressure cylinder $6\frac{1}{2}$ ins. in diameter by 8 ins. stroke in each case. The cylinders are cast integral, and all the wearing surfaces are made extra large and are case-hardened where necessary, so as to render the engine suitable for quick running. The working parts of the engine are enclosed in an oil-tight casing, and work in an oil bath. The piston speed is 350 revolutions per minute. The reversing gear is of Mann's patent single eccentric type (Fig. 70), which can be notched up, and can thus be utilized as a third brake, when required. The engine is placed between the side plates to avoid a separate oil-bath, and to allow of the quick-running gear being in the same bath.

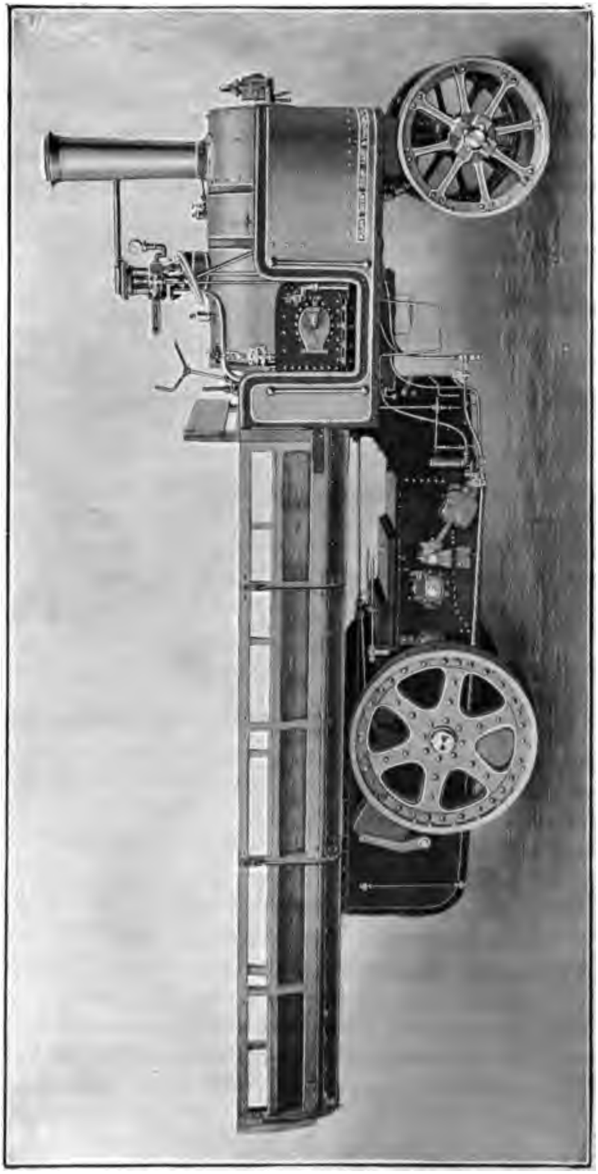

Fig. 66.—Mann heavy-freight steam vehicles. Standard 5-ton lorry with rigid body.

The crank shaft, intermediate shaft, and axles are of forged steel, supported in long hardened gun-metal bearings carried in steel brackets, having turned projections which fit accurately into holes of large diameter bored in the horn plates, thus relieving the bolts from the working strain of the engine.

The gearing is all of cast steel, two speeds being provided, viz. a fast one of 5 miles per hour, and a slow one of 2½ miles per hour, no pitch chains being used, and compensating gear being provided for turning corners.

The boiler (which is shown in Figs. 68 and 69) is of the horizontal locomotive type, strongly stayed, and fitted with a firebox suitable for burning either coke or smokeless coal. It is constructed of Siemen-Martin mild steel plates, the edges of which are planed, and the riveting is effected by hydraulic machinery. The firebox shell sides are extended for carrying the engine shafts and axle brackets, all of which pass through the same plates. The working pressure of the boiler is 200 lbs. per square inch.

The boiler feed pump is of gun-metal, fitted with phosphor bronze valves of large diameter, it is continuous acting, and the feed to the boiler can be regulated to a nicety. Either an auxiliary donkey pump or an injector is also provided for supplying the boiler when the engine is standing. The feed water is stored in a tank carrying 120 gallons of water, and a water lifter, fitted with 20 feet of suction hose, is provided for filling this tank with water from a wayside brook or pond.

Steering is effected by means of a simple but effective gearing, comprising a worm arranged to mesh directly with a toothed quadrant cast on the fore-carriage bracket. Two brakes are provided, viz. a foot lever strap brake, and a screw brake acting on the rims of the lorry road wheels.

The engine is practically a small compound road locomotive mounted upon springs, with coke bunkers round the boiler and a footplate at one side of the firebox, the water tanks being at the other.

The body of the lorry is constructed of mild steel plates flanged at the corners, and strongly braced and stayed by angle irons.

The exhaust from the engine is passed through a separator near the chimney to remove water, and afterwards through a tubular superheater before being discharged into the lower part of

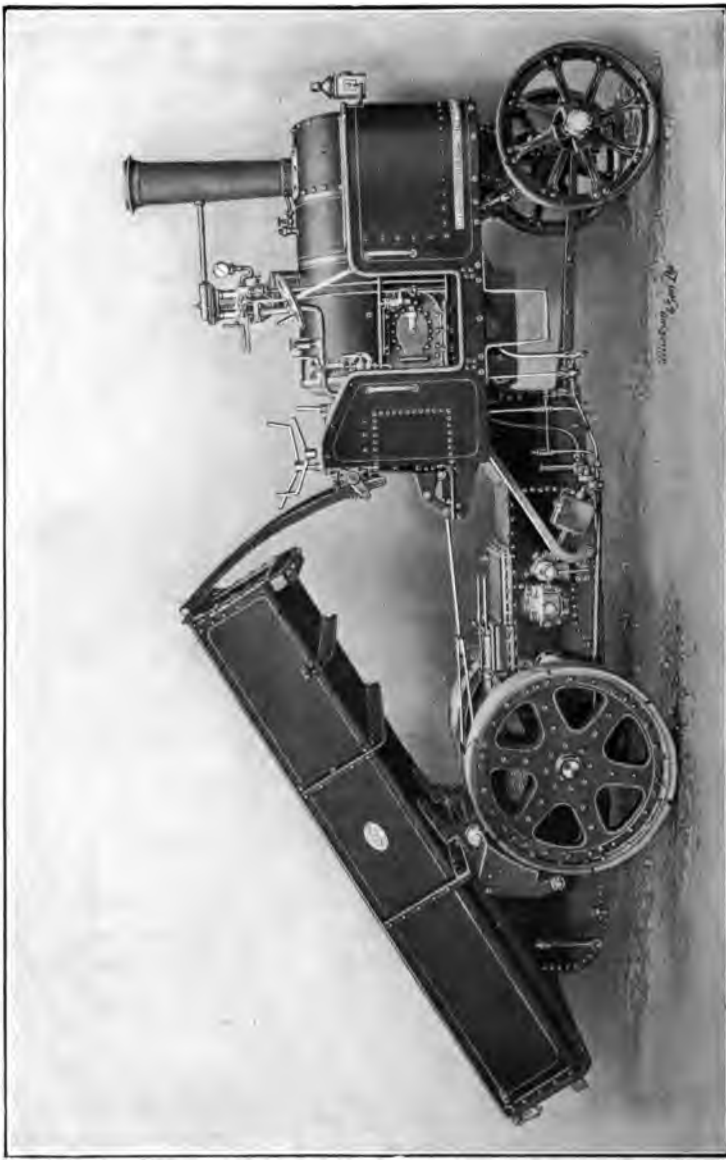

Fig. 67.—Mann heavy-freight steam vehicles. Standard 5-ton lorry with tipping body.

the chimney and passing away into the atmosphere in a thoroughly dried and invisible condition. By this arrangement, and the good blast maintained, no steam remains in the uptake.

The lorries are capable of carrying loads up to 5 tons, and, in the case of the tipping lorry, a suitable windlass is provided for hauling back the body after the load has been tipped. The vehicles are capable of surmounting gradients of 1 in 5, and the fuel consumption is light, 14 lbs. of ordinary gas coke per mile being sufficient when fully loaded.

Figs. 68 and 69 are respectively a vertical longitudinal central

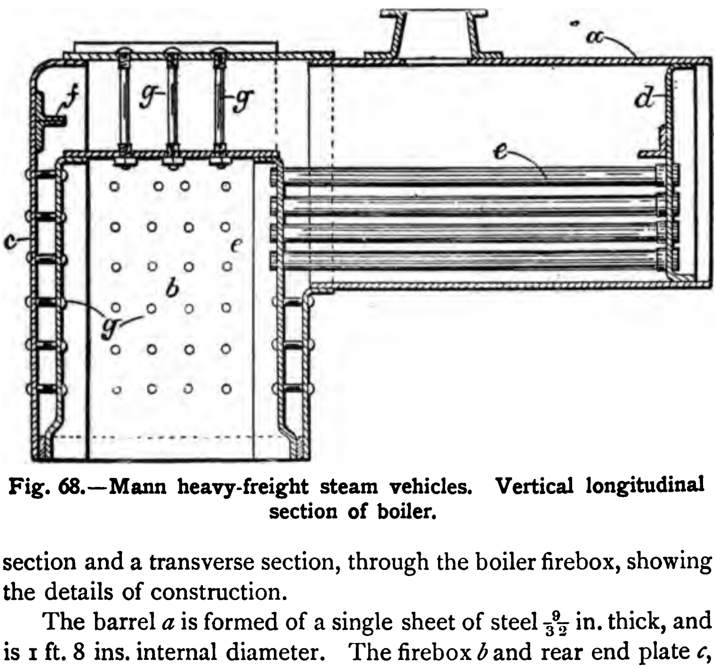

Fig. 68.—Mann heavy-freight steam vehicles. Vertical longitudinal section of boiler.

section and a transverse section, through the boiler firebox, showing the details of construction.

The barrel *a* is formed of a single sheet of steel $\frac{9}{32}$ in. thick, and is 1 ft. 8 ins. internal diameter. The firebox *b* and rear end plate *c*, are of $\frac{5}{16}$ in., and the front plate *d* of $\frac{3}{8}$ in. steel plate, the rivets being $\frac{5}{8}$ in. diameter, and the pitch in the case of single joints $1\frac{11}{16}$ in., and of double joints $2\frac{1}{4}$ ins., the rows in the latter case being $1\frac{3}{8}$ in. apart, and placed zigzag. Double joints are provided at the longitudinal barrel seam, the crown and horn plate joint, and the back plate and horn plate joint. The tubes *e*, of which there are 24, are of steel, $1\frac{3}{4}$ in. diameter by 36 ins. in length, and

are enlarged to $1\frac{7}{8}$ in. at the smoke-box end. The rear end plate *c* is stiffened by two angle irons, *f*, placed back to back. The side plates for supporting the frame are $\frac{5}{16}$ in. thick, and are riveted to the firebox 1 ft. 10 in. apart, the top and bottom plates constituting a girder on which are bedded the engine and water tanks, and which plates are longer in the case of the non-tipping or rigid bodied lorry; *g* are the stays.

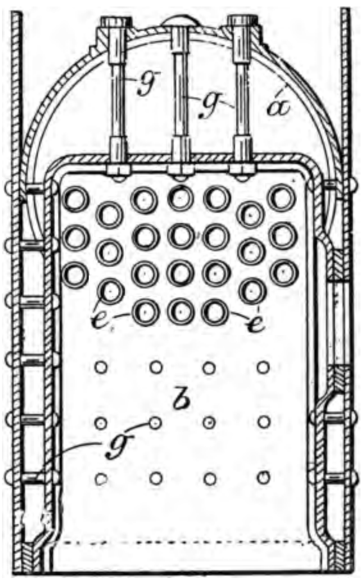

Fig. 69.—Mann heavy-freight steam vehicles. Transverse section of boiler.

In the latest designs the boiler is made separate from the side plates so as to be capable of being easily removed for repairs, etc.

As before mentioned, a patent type of single eccentric reversing gear is used, and the construction of this device (shown in Fig. 70) is simple, being substantially as follows: A wheel *b*, having four lugs, carrying pins, or projections, which form fulcrums for a bell-crank lever, *c*, and a distance lever, *d*, is keyed on the crank shaft *a*. The bell-crank lever *c* and distance link *d* are equal in depth to the diameter of the shaft *a*, and they are provided with pin centres of precisely equal length. An eccentric *e* is formed with similar lugs to those on the wheel *b*, which are arranged to receive pins by which it is connected to the ends of the bell-crank lever *c* and distance link *d*. The bell-crank lever *c* can be moved laterally along the crank shaft *a* by means of a hand lever operating on a sleeve connected to the former. The eccentric *e* can be shifted from the position for full forward to that for full backward gear, whilst the amount of lead remains unaltered, and the cut-off can be varied in the same manner as in a link motion by notching up. Advantages claimed for this arrangement are that no particular parts are subjected to an

abnormal amount of wear, as the eccentric is maintained in a fixed position; and, moreover, that comparatively little space is taken up.

The driving wheels consist of two pressed steel flanged plates, and a **T**-section steel rim rendered additionally stiff by a rolled steel tyre. The hubs or naves are steel castings fitted with phosphor bronze bushes.

The toothed pinions on the crank shaft are forged and cut from the solid, and the whole of the rest of the spur or toothed gear wheels used on the vehicles are of cast steel.

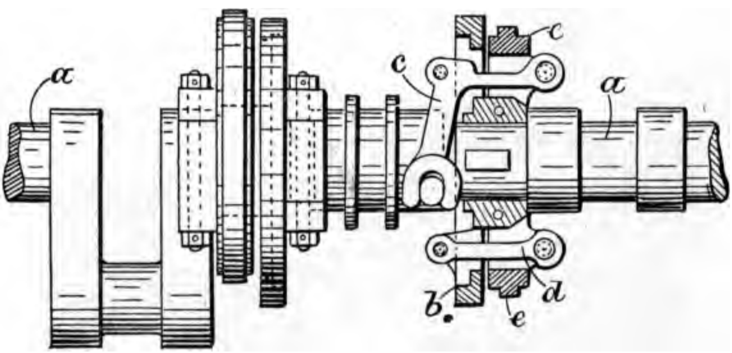

Fig. 70.—Mann heavy-freight steam vehicles. Patent single eccentric reversing gear.

The vehicles shown in Figs. 65 and 66, not having the divided road wheels of the original pattern, are much simpler, and, moreover, as there are no outside brackets, the wheels can be easily removed. The whole machine, besides, is heavier and stronger and better sprung, and the increased tare weight allows of bunkers for fuel round the boiler, which takes off the traction-engine appearance which was a somewhat prominent feature in the old type of vehicle.

Thornycroft Heavy-freight Steam Vehicles

The Thornycroft Steam Waggon Company, Limited, of Chiswick and Basingstoke, are makers of a number of different patterns of heavy-freight steam vehicles, the performance of which at the trials held by the Liverpool Self-propelled Traffic Association

attracted considerable attention, and, in conjunction with their success in practical work, has stamped them as reliable and trustworthy vehicles.

Amongst the types of heavy-freight steam vehicles manufactured by this company, mention may be made of their standard waggons adapted for loads of from 2 to 4 tons; box vans carrying loads up to 2 tons and up to 4 tons; lorries with rim sides and dwarf tail-boards, with rail sides, and side-loading lorries, to carry loads up to 4 tons, and lorries with rail or board

Fig. 71.—Thornycroft heavy-freight steam vehicles. Colonial type of 4-ton waggon.

sides to carry loads up to 6 tons; combination lorry and furniture vans to carry loads up to 4 tons; waggons with rail sides, and with rail sides and wooden roofs, to carry loads up to 4 tons; colonial waggons to carry loads up to 4 tons, and to 6 tons; also tipping waggons adapted for municipal purposes, military waggons, etc.

A typical example of the Thornycroft heavy-freight vehicle is the colonial waggon, shown in Fig. 71. This waggon is built in two sizes, viz. that shown in the illustration, which is adapted to carry a load of 4 tons, and a larger vehicle adapted to carry a load of 6 tons. Under ordinary conditions the first-mentioned

vehicle is capable of drawing a trailer carrying an additional load of from 2 to $2\frac{1}{2}$ tons.

The framework of the colonial waggon is, like the standard waggon for home use, made of channel section steel strongly tied and braced, but is in the former case constructed stronger throughout, a remark which also applies to other parts, the springs being stiffer and the driving axle-boxes being provided with extra stays. Instead of the wooden artillery pattern wheels used on the home type of waggon, which are similar to those already described and illustrated (Figs. 32 and 33) with reference to the Thornycroft heavy passenger vehicles, wheels made entirely of steel and of larger diameter are employed. The tyres are made up to 12 inches in width, and are fitted with diagonal cross strips.

The engine and boiler are also similar to those described and illustrated (Figs. 34 to 36) with reference to the heavy passenger vehicles, the first mentioned, however, being much more powerful and developing 45-horse-power at normal speed, whilst the boiler is, of course, proportionately larger. The gearing is all enclosed in dust-proof oil-tight gear cases.

The vehicle, when fully loaded, is capable of travelling at a speed of about 6 miles an hour on fair roads, and can surmount gradients of 1 in 9. A daily average of from 35 to 40 miles can be made, one day a week being devoted to cleaning of boiler and general overhaul. Sufficient water is carried for a run of 15 to 20 miles under ordinary conditions.

The boiler is arranged for burning coal, coke, or good burning wood as fuel, and the bunkers have a sufficient capacity to store enough coal for a run of about 50 miles. When desired, the boiler can be adapted, and the necessary arrangements fitted, to burn crude or other oil as fuel.

These vehicles can be supplied with any type of body, the frame and running gear remaining practically the same in each instance.

Coulthard Heavy-freight Steam Vehicles

The firm of Messrs. T. Coulthard and Company, Limited, of Preston, have also gained a reputation for the various types of heavy-freight steam vehicles which they build, Figs. 72 and 73

being two views of one of their 5 to 6 ton lorries showing the vehicle loaded and unloaded.

The principal dimensions of this vehicle are: length over all, 19 ft. 9 ins.; width over all, 6 ft. 6 ins.; height over chimney, 8 ft. 10 ins.; platform, 14 ft. by 6 ft. 6 ins.; area of carrying platform, 91 square feet.

The main frame is of channel steel, braced and so designed and constructed as to carry the whole of the machinery, boiler, water tank, etc. The frame is supported on the axles through long laminated springs.

The engine is of the vertical compound condensing type, fitted

Fig. 72.—Coulthard heavy-freight steam vehicles. Standard 5 to 6 ton lorry, loaded.

with link motion reversing gear, and enclosed in an oil-tight casing, which latter is extended so as to also carry enclosed all the reducing and compensating gear and shafts, and to ensure very efficient lubrication of the splash type.

From the engine motion is communicated to the driving wheels by means of chain transmission gearing operating through a countershaft.

The boiler is of the vertical fire-tube doorless type, the fuel, which is coal or coke, being fed in from a central aperture at the top, and it is calculated to withstand a working pressure of 200 lbs. per square inch, being hydraulically tested to 400 lbs. per square inch. The boiler feed pump is of a patented

dust-proof type designed by the makers, and connected directly to the engine, an independent steam pump being also fitted as an emergency feed. Both these pumps are fitted with independent motion and delivery from the feed-water tank to the boiler. The fuel bunker has a capacity of 4 cwts., which is sufficient for a run of about 30 miles, and the feed-water tank is capable of holding a sufficient supply of water to last for from 12 to 15 miles.

The wheels are of the artillery pattern, or gun-carriage construction, fitted with steel hubs, oak spokes, and ash felloes, the

Fig. 73.—Coulthard heavy-freight steam vehicles. Standard 5 to 6 ton lorry, unloaded.

tyres being of weldless steel hydraulically fitted, 5 inches in width to front, and 7 inches in width to rear wheels. The front wheels are 33 inches in diameter, and the rear wheels 36 inches in diameter. The drive is transmitted to the road-driving wheels through an improved patented triangular attachment which communicates the driving effort direct to the felloes or rims of the wheels and relieves the spokes of this strain.

Double-acting brakes are fitted to the road-driving wheels, which brakes are sufficiently powerful to be capable of holding the vehicle on any reasonable gradient in either direction.

There are two speeds of gearing provided, viz. a fast one of 5 miles an hour, and a slow one of 2½ miles an hour, and the

vehicle is capable of carrying the full load; that is to say, from 5 to 6 tons on good macadam or paved roads, and of surmounting therewith grades not exceeding 1 in 10. On bad roads or gradients exceeding the above, the load will have to be reduced to meet the circumstances of the case. The tare weight of the vehicle is approximately 4·75 tons.

The Lancashire Steam Motor Company Heavy-freight Steam Vehicles

The heavy motor vehicles manufactured by this company, who, it may be remarked, built a steam motor lorry capable of carrying a load of 4 tons and fitted with a coal-fired boiler as far back as

Fig. 74.—The Lancashire heavy-freight steam vehicles. Brewer's waggon.

1883, have been very successful at Liverpool and elsewhere, and have attracted very favourable attention.

The standard type of steam road waggon (Fig. 74) built by these makers has a vertical boiler located as in the Thornycroft waggon at the extreme fore end of the frame, instead of just

behind the front wheels, as is the practice with some other makers.

The waggon has a platform of the ordinary lorry type, 12 ft. 6 ins. in length by 6 ft. 5 ins. in breadth over all. The available space for goods inside the beading is 75 square feet. The main frame supporting the platform is entirely constructed of channel steel. When loaded with 4 tons the height of the platform from the ground is 3 ft. 6 ins.

The wheels are of the artillery pattern, having steel naves,

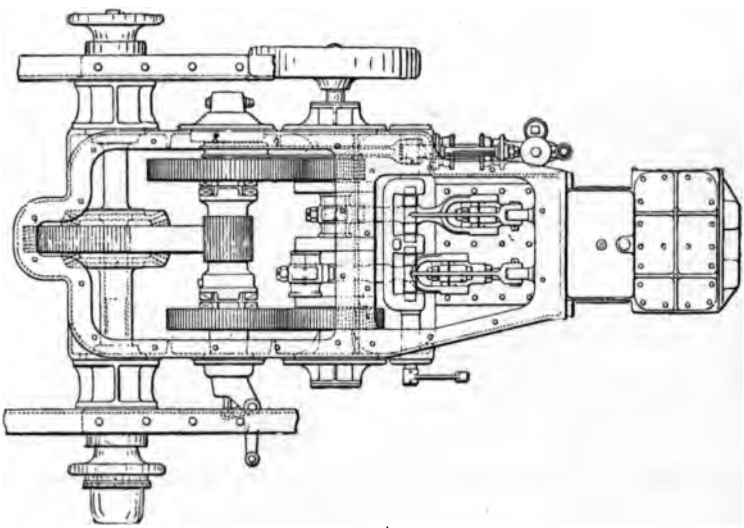

Fig. 75.—The Lancashire heavy-freight steam vehicles. Plan view of engine.

oak spokes, and ash felloes, the front wheels being 34 inches in diameter with tyres 4 inches wide, and the rear or driving wheels 36 inches in diameter with tyres 5 inches wide. The tyres are weldless and specially rolled, and are put on by hydraulic pressure.

The engine (Fig. 75) is of the horizontal compound reversing type, having cylinders $3\frac{1}{2}$ ins. and 6 ins. diameter by 6 ins. stroke, and running at a speed of 420 revolutions per minute. The engine, change gear, and compensating gear are all completely enclosed in an oil-tight and dust-proof casing providing efficient

lubrication of the splash type. The wearing surfaces are all exceptionally long and large, and an arrangement is provided for admitting high-pressure steam to both cylinders when required.

The valve gear is shown in Fig. 76. The valves are of the balanced type, specially designed, and devoid of springs or complications liable to give trouble.

The boiler for generating the necessary steam supply, which is shown in vertical central section in Fig. 77, and as before

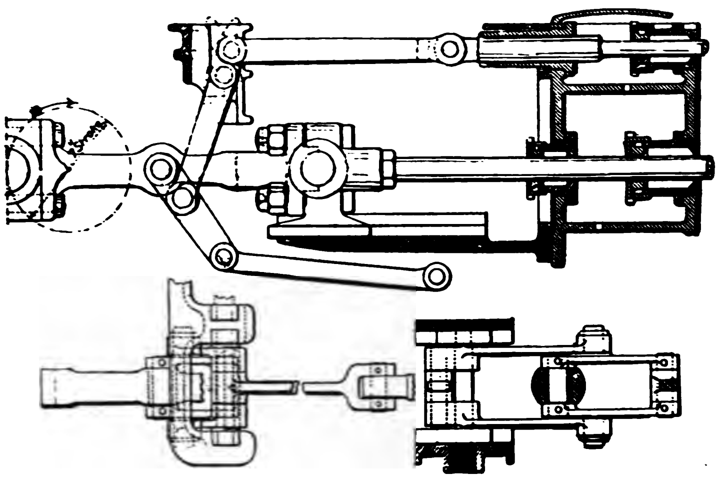

Fig. 76.—The Lancashire heavy-freight steam vehicles. Views of valve gear.

mentioned, is placed in front of the driver's seat, is of the fire-tube type, fired from the top through a central chute, the fuel used being gas coke. The tubes are of tough seamless steel, and a fusible plug is fixed in the crown plate of the firebox. The boiler has 110 sq. ft. of heating surface, and 4·9 sq. ft. of grate area, the working pressure being 200 lbs. per sq. in. The fire is regulated by a hinged ashpan, and also by a lid covering the central firing chute.

Feed water is supplied to the boiler by an automatic feed pump working off the compensating gear shaft, and an arrangement is provided whereby any feed water in excess of that required to feed the boiler is pumped back into the feed-water

tank, this operation being regulated by means of a hand wheel near the driver's seat. A small steam pump is also provided beneath the driver's seat, which can be used as an auxiliary boiler

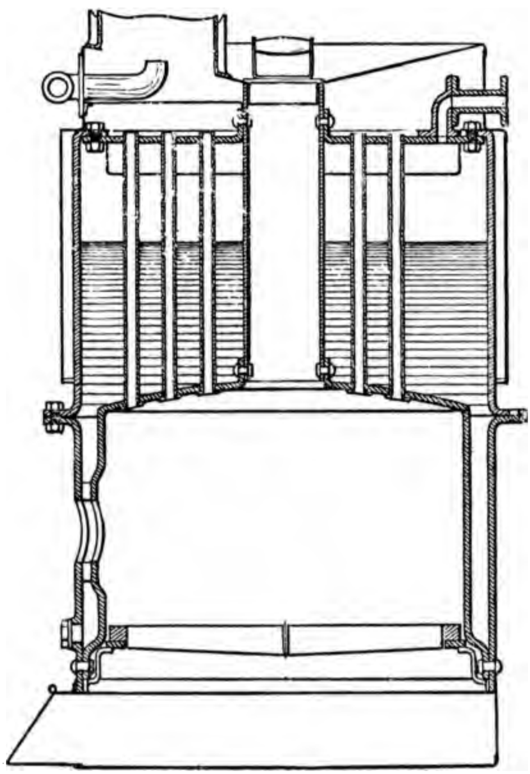

Fig. 77.—The Lancashire heavy-freight steam vehicles. Vertical central section of boiler.

feed pump. Double check valves are fitted to both these boiler feed pumps.

The fittings include a Klinger safety water gauge and a safety valve set to blow off at 250 lbs. pressure per square inch. The boiler gives 80 sq. ft. of heating surface, is tested to a pressure of 425 lbs. per square inch by hydraulic pressure, and is intended to work at a pressure of 200 lbs. per square inch.

The fuel bunkers are located on each side of the boiler, and are capable of containing a sufficient supply of coke to last for an ordinary day's work.

The feed-water tank has a capacity of 130 gallons, and is fitted with a removable strainer, a water lifter being provided for filling same.

The boiler is so designed that it can be readily taken to pieces for cleaning purposes, the upper and lower shells being bolted together, as shown in the drawing.

The whole of the gearing is steel, all the wheels having machine-cut teeth, and the drive from the end of the compensating gear shaft is applied to the driving-wheel felloes by an improved form of Hans Renold's patent roller chain, which has all the links

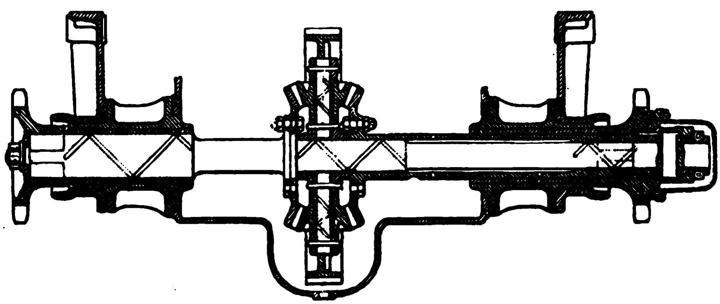

Fig. 78.—The Lancashire heavy-freight steam vehicles. Sectional view of compensating gear transmission shaft.

bushed with hardened steel, and large diameter steel pins also hardened. The Renold chain is one particularly well suited for heavy motor work, as it meets in a most effective manner the alterations of pitch due to wear, and also reduces the wear upon the pins to a minimum.

An important feature in the transmission gear is the arrangement of cushion drive in the small pinions on the compensating gear shaft, by means of which the driving chains, and working parts of the engine, are relieved of all shocks and injurious strains when starting under a heavy load, the arrangement being such that the engine crank shaft can make almost a complete revolution before full power is exerted at the driving wheels.

The compensating gear shaft, which is shown in Fig. 78, is of

special construction, being hollow or tubular from end to end, and a bolt passing through this shaft is arranged to take up the end thrust caused by the bevel or mitre wheels, and thereby to relieve the bearings of same, and in this manner to effect a very considerable reduction in the amount of friction engendered. No keys are employed in the construction of the mechanism, all the wheels being put on flanges, and castellated nuts are used throughout, each being secured by a split pin. The parts are all made to gauge and template, and are interchangeable, and all the castings being numbered makes it a comparatively easy matter to obtain replacements. An internal clutch arrangement, which can be operated by means of a lever placed under the frame of the vehicle, admits of the compensating gear being

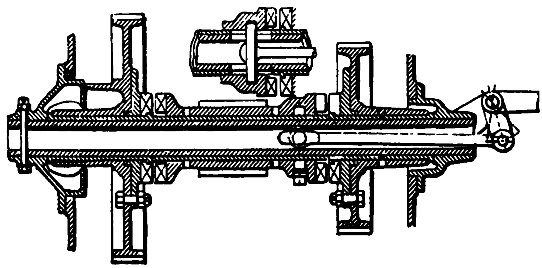

Fig. 79.—The Lancashire heavy-freight steam vehicles. Sectional view of second motion shaft.

locked when desired. Fig. 79 shows the construction of the second motor shaft.

The driver's seat is capable of accommodating comfortably three persons, one man, however, being sufficient to handle the machine.

This waggon is stated by the makers to be capable of performing a journey of 50 miles in a day of 12 hours, with a load of 4 tons, provided that the roads are in good condition and the gradients not too severe.

Savage Heavy-freight Steam Vehicles

Although Messrs. Savage Brothers, Limited, of King's Lynn, have been long well known as makers of traction engines, it is only comparatively recently that they have turned their attention

to the manufacture of steam motor lorries. They have, however, succeeded—by utilizing their long experience in road traction to very great advantage—in the production of a very efficient heavy motor vehicle of this description.

The following are the principal dimensions of Messrs. Savage's standard type of steam lorry, shown in Fig. 80: extreme length, 18 ft.; width, 6 ft. 6 ins.; height of floor, 4 ft.; floor space, 75 sq. ft.; diameter of front wheels, 33 ins., width of tyres, 5 ins.; hind wheels, 39 ins., width of tyres, 7 ins. The frame is of special channel steel, strongly riveted and bolted together.

Fig. 80.—Savage heavy-freight steam vehicles. Standard 5-ton lorry.

The engine is of the horizontal compound piston valve type, cylinders respectively 4 ins. and 7 ins. diameter giving off 30 brake horse-power at 450 revolutions per minute. The crank shaft, connecting rods, piston rods, and guide bars are of steel, and the reversing gear is of the single eccentric type, the whole being enclosed in an oil-tight and dust-proof casing, and a Rochester pony pump lubricator being provided for cylinder lubrication.

The boiler, which is situated at the front end of the vehicle, is of the water tube type, the circulating tubes being $\frac{3}{4}$ in. diameter, and the return tubes $1\frac{1}{8}$ in. diameter, of Maunesmana steel manufacture and solid drawn. The bottom tube plate is of mild

steel, having a steel-domed cover to which are attached patent accessible inlet valves and blow-off cock. The upper steam and water dome is of malleable steel and solid drawn, having fixed to it the usual steam gauges, safety valves (Empire type), steam stop valves, and cocks for supplying steam to engine water lifter and auxiliary steam pump. The outer casing is of mild steel lined with asbestos sheets.

The boiler is fitted with a Klinger water gauge, and doors are provided at each end to admit of easy access being had to the tubes. It has a heating surface of 90 sq. ft. in tubes, and 4 sq. ft. of grate area. The working pressure is 220 lbs. per square inch. There are two feed pumps, an ordinary and an auxiliary.

A feed-water tank having a capacity of 130 gallons is provided, and there is bunker capacity for 3 cwts. of fuel. There is steel spur gearing giving two speeds, with machine-cut teeth and compensating gear on the intermediate shaft with a special locking arrangement. The consumption of coke is 2 lbs. per ton per mile, and the water consumption 8 to 10 gallons per mile.

In working, the exhaust steam is discharged into a copper cylinder or receptacle, thereby heating the feed water on its way to the boiler, which feed water passes through a copper coil arranged within this cylinder. The exhaust steam is subsequently discharged through the chimney as invisible vapour.

The average speed of the vehicle is 5 miles an hour, and the load from 4 to 5 tons. At a recent trial near King's Lynn the author saw one of these steam waggons, fully loaded, successfully surmount a gradient of 1 in 7.

Clarkson Heavy-freight Steam Vehicles

Messrs. Clarkson, Limited, Chelmsford, are the makers of excellent steam lorries, the running mechanism of which is substantially similar in construction to that of the steam public service omnibuses made by the same company, and which, having been already described at some length on pp. 79 to 103, need be no further dealt with here.

Musker Heavy-freight Steam Vehicles

Messrs. C. and A. Musker, Liverpool, manufacture heavy steam motor vehicles which differ from any of those already

described, in having a horizontal boiler of the flash or instantaneous generation type, which is placed transversely under the centre of the body frame, and fired with liquid fuel, a special fan creating a draught for the burner and enabling a chimney to be dispensed with. In this system, moreover, a separate auxiliary engine is provided, which both supplies oil and air to the burner, and feed water to the boiler, in the proper proportions. The air for the burner is drawn through the condenser, and is thus raised in temperature before being delivered by the fan into the combustion chamber.

Fig. 81 is a vertical longitudinal central section showing the

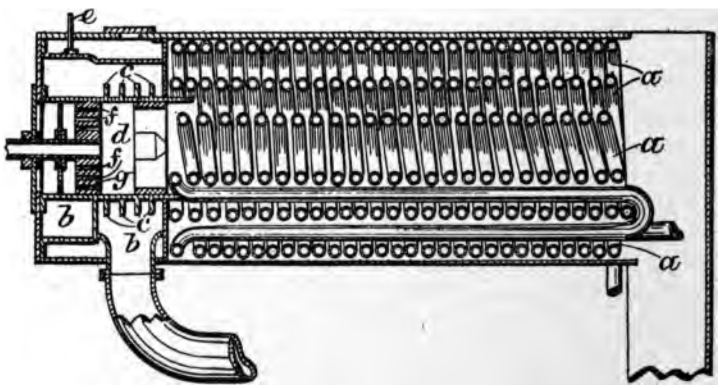

Fig. 81.—Musker heavy-freight steam vehicles. Vertical longitudinal section of boiler.

Musker boiler, which, it will be seen, consists of three cylindrical steel tube coils, *a*, through the annular space or clearance between which the flames from the burner pass. The air passes inwardly through the heated passage *b*, into which project ribs or gills, *c*, on the wall of the ignition chamber *d*. The oil is dropped in through the pipe *e*, on to the hot wall of the ignition chamber *d*, where it is instantly vapourized and mixes with the heated air, being further mixed before reaching the ignition or combustion chamber *d*, by passing through holes, *f*, in a block, *g*.

The engines are placed horizontally, and approximately in the centre of the vehicle, motion being transmitted to the driving wheels by means of toothed gearing. An advantage offered by

the Musker system is the large platform area available for the accommodation of goods.

Simpson-Bodman Heavy-freight Steam Vehicles

Messrs. Simpson and Bodman build a type of motor waggon characterized by the use of a pair of small three-cylinder engines working separately and independently the two driving wheels, thus enabling differential gearing to be dispensed with. Motion is transmitted from each of the engines to its countershaft by means of interchangeable toothed wheels, admitting of change of speed gear being readily effected, and the drive is transmitted from the countershafts to the road wheels by chain gearing. The position of the engines and gearing at the rear of the vehicle both renders them readily accessible and distributes their weight on the driving wheels, which is advantageous when running empty.

The boiler employed, which is shown in sectional front and side elevation in Fig. 82, and is of the flash or instantaneous

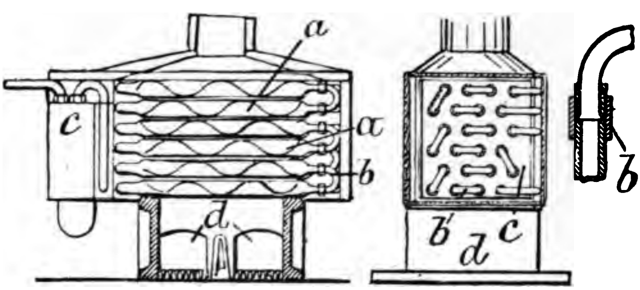

Fig. 82.—Simpson-Bodman heavy-freight steam vehicles. Sectional front and side elevations and detail view of boiler.

type, and is said to be one of considerable efficiency. It consists essentially of a set of heavy steel tubes, *a*, which are indented in a similar manner to those of the Row condenser, and are connected on the exterior of the furnace by Haythorn joints, *b*, one of which is shown in vertical central section, drawn to an enlarged scale on the right-hand side of the illustration. These indentations occurring a large number of times so baffle the passage of the water or steam as to expose the same thoroughly to the

action of the heated surfaces. *c* is a dome to receive the steam and prevent its attaining too high a temperature. *d* is the furnace which is adapted for the consumption of coal.

Brightmore Heavy-freight Steam Vehicles

The latest standard pattern of steam lorry from the designs of Dr. A. W. Brightmore, M.I.C.E., is shown in Fig. 83. A lorry on this system formed, it will be remembered, a conspicuous exhibit at the Stanley Show a year or two ago. The Brightmore steam vehicles are now built by Messrs. Turner, Atherton and Company, Limited, Denton, Manchester.

Fig. 83.—Brightmore heavy-freight steam vehicles. Standard 5 to 6 ton lorry.

The driving and steering of this lorry are both effected on the front wheels; and a special feature in the construction is that, contrary to the usual practice in lorries designed with front steering and driving wheels, the entire weight of the machinery is supported on them, thus ensuring sufficient adhesion when running light, whilst the construction at the same time admits of the steering being readily operated. The machinery is carried on the undercarriage, and a platform on the latter, extending in front of the lorry, is provided for the driver, all the handles necessary for the control of the vehicle being within his reach.

The steering gear consists of an arrangement of brake-drums

placed on each side of the differential gear, and the steering is performed by applying the one or other of these brakes, and thus causing the one or other of the front wheels to slow down and the other wheel to run at an increased speed, according to the direction in which it may be required to steer. The sensitiveness of the steering is controlled by means of a resistance which has to be overcome by the steering brakes, and is capable of adjustment to suit the average road surfaces in any particular district.

A special form of water-tube boiler is provided for the generation of steam, and the motive power is derived from a standard type of compound cased-in engine, which drives on to the front wheels through a second or auxiliary motion shaft and a differential gear shaft through Renold's silent chains. The cylinders are $4\frac{1}{2}$ ins. and $7\frac{1}{2}$ ins. diameter by 6 ins. stroke. The cranks are at right angles, giving a nearly uniform effort on the crank pin, and thus permitting a fly-wheel to be dispensed with. The normal speed of the engine is 500 revolutions per minute, and it is geared down to give a speed of 6 miles per hour on the road, whilst this speed can be varied either by the throttle valve or cut-off gear. A slow-speed gear is, however, also provided for very steep hills, but the variable cut-off makes its use seldom necessary.

The lorry under consideration has a carrying capacity of from 5 to 6 tons, and the dimensions of the carrying platform are 16 ft. by 7 ft. 3 in., one of the advantages of the design being that this platform extends practically the whole length of the vehicle. The over-all length of the vehicle is $18\frac{1}{2}$ ft. The frame is of rolled steel bulb angle section, and the platform flooring of $1\frac{1}{2}$-in. pitch pine. The wheels are of the artillery pattern, 3 ft. 3 ins. diameter, with 8-in. treads.

Another advantage claimed for this type of lorry is that the load is carried on all four wheels, thus effecting a reduction of the maximum resulting pressure on the roads.

The steering is undoubtedly very sensitive, being always exerted on the direction of motion, and, owing to the short wheel base, the vehicle can be turned in a short radius.

The forecarriage carrying the machinery is connected to the carrying platform by a ball-and-socket joint, and is kept parallel to it by a roller (connected to the back of the forecarriage) moving in a segmental channel attached to the platform. This

method of connection permits the front axle to assume any angle relative to the back axle whether in the horizontal or vertical plane, thus permitting of steering, and of the vehicle accommodating itself to any unevenness of the ground without a strain on the springs. Both splash and forced lubrication are employed.

Straker Heavy-freight Steam Vehicles

Fig. 84 shows the standard pattern of covered steam waggon, adapted for a load of 5 tons, built by the Straker Steam Vehicle Company, London. The 5-ton Straker vehicles are fitted with

Fig. 84.—Straker heavy-freight steam vehicles. Standard 5-ton covered waggon.

long-stroke slow-running engines of 40 indicated horse-power of the compound open horizontal type, which affords the advantage of permitting of ready access to the working parts. The cylinders are 4 ins. and 7 ins. diameter by 7 ins. stroke, and the reversing gear is of the single eccentric type, and has been designed with the view of keeping the mechanism as free as possible from valve rods, etc. The cylinders are lagged with non-conducting material, covered with a casing of planished steel, and a bye-pass is provided for the admission of live steam into the low-pressure cylinder at starting, or at any other time when extra power is required. The bearings

are of gun-metal or phosphor bronze, and a continuous system of oil feed is provided.

The engine is protected from dust by a light casing, which is normally held in position by two sliding bolts, and can be easily removed when required. A fly-wheel is mounted on the crank shaft, and the engine can be readily disconnected and run independently from the car. The crank shaft has a square extension upon which is arranged to slide a double steel pinion, which can be thrown into or out of gear by suitable actuating gear, and this

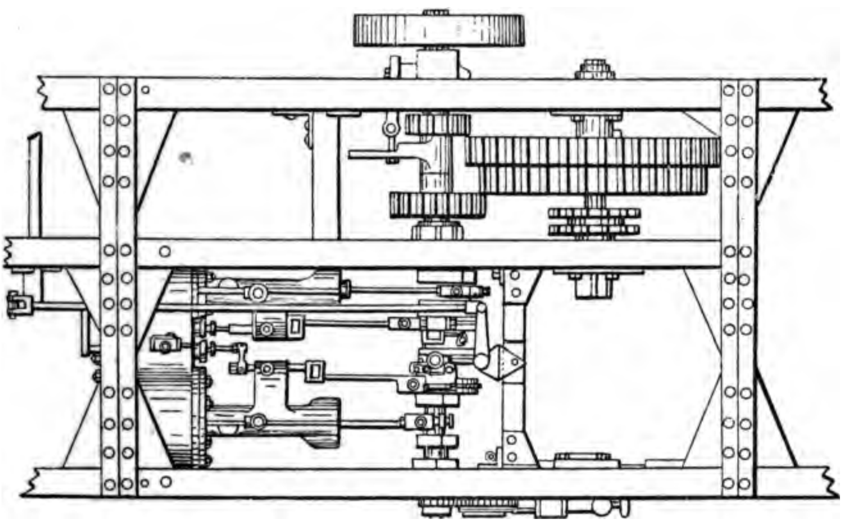

Fig. 85.—Straker heavy-freight steam vehicles. Plan view of engine and running gear with covers removed.

pinion meshes with steel gear wheels mounted on a countershaft rotatably mounted on a channel frame carrying a sprocket pinion. Fig. 85 is a plan view of the engine and running gear with the covers removed.

Two speeds are provided, the ratios of the gear being 9·2 to 1 and 16·7 to 1, which give speeds of from 3 to 7 miles an hour. Power is transmitted to the rear axle (shown in Fig. 86), which is of the live type, and rotates in axle boxes fitted with phosphor-bronze bearings and having grease-pad lubrication, by means of a compound silent antifriction roller chain.

The chain-drive sprocket wheel is mounted on a differential gear, one bevel wheel of which is keyed to the rear axle, and the other to the driving sleeve secured to one of the driving wheels. A special arrangement is also provided for admitting of the insertion of a locking pin in any position of the wheels, so as to connect up both driving wheels when desired. A radius rod extends from each axle box to a lug on the countershaft bearing, each rod having screw and nut adjustment. All the wearing surfaces are case-hardened.

The boiler, which is mounted over the front or steering axle, is shown in sectional plan in Fig. 87, and in vertical central section in Fig. 88. It is of the water-tube type, and has 70 sq. ft. of heating surface, and 2·2 sq. ft. of grate area. The working

Fig. 86.—Straker heavy-freight steam vehicles. View of rear axle.

pressure is 205 lbs. per square inch. It consists essentially of four concentric shells forming an inner and outer annular water space, closed at top and bottom by rings connected together by stay bolts. Between the two annular water spaces are radial connecting tubes. This arrangement is claimed to ensure absolutely equal expansion of the parts, and to avoid leaky tubes; and no rivets being used, the boiler can be easily taken to pieces when desired. The smoke box is so arranged that it can be readily disconnected when the flues are exposed for cleaning, and a superheater is attached to the fire box. A reheater is also provided for dealing with the exhaust steam. Coke fuel is employed, the feed being through a central down-take, and a regulating damper is provided in the base of the funnel. Normally the necessary draught is secured by the discharge of the exhaust steam into the funnel through a nozzle, but a live-steam blower is also fitted. Both an injector and a gear-driven plunger pump are provided for feeding the boiler, either of them being of ample capacity singly.

The rear portion of the body is supported upon strong springs mounted upon the bearings carrying the driving axle, and connected with the frame by adjustable radius rods. The fore part of the body is supported upon the front axle through a powerful spring cradle and an antifriction or ball bearing, the axle being mounted in a central pivot, thus securing a three-point support and obviating any undue twisting strain.

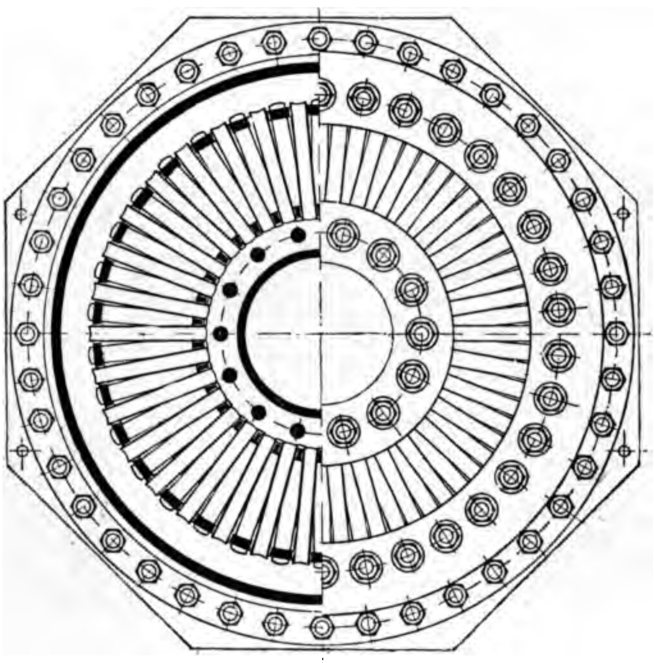

Fig. 87.—Straker heavy-freight steam vehicles. Sectional plan view of boiler.

The road wheels are made of mild steel, with special cast-iron hubs. The driving wheels are 3 ft. 6 ins. by 9 ins. tread, with tyres $\frac{3}{4}$ in. thick. The front or steering wheels are 2 ft. 6 ins. by 5 ins. tread, with tyres $\frac{5}{8}$ in. thick, the tyre plates being cut in sections in order to provide for expansion.

The steering is by steel worm and segment, with an inclined spindle and an aluminium hand wheel. A powerful block or shoe

brake is provided, and a second brake can be obtained by reversing the engine. The body is built of well-seasoned timber ribbed up with angles, plates, and beads, and has a superficial area of

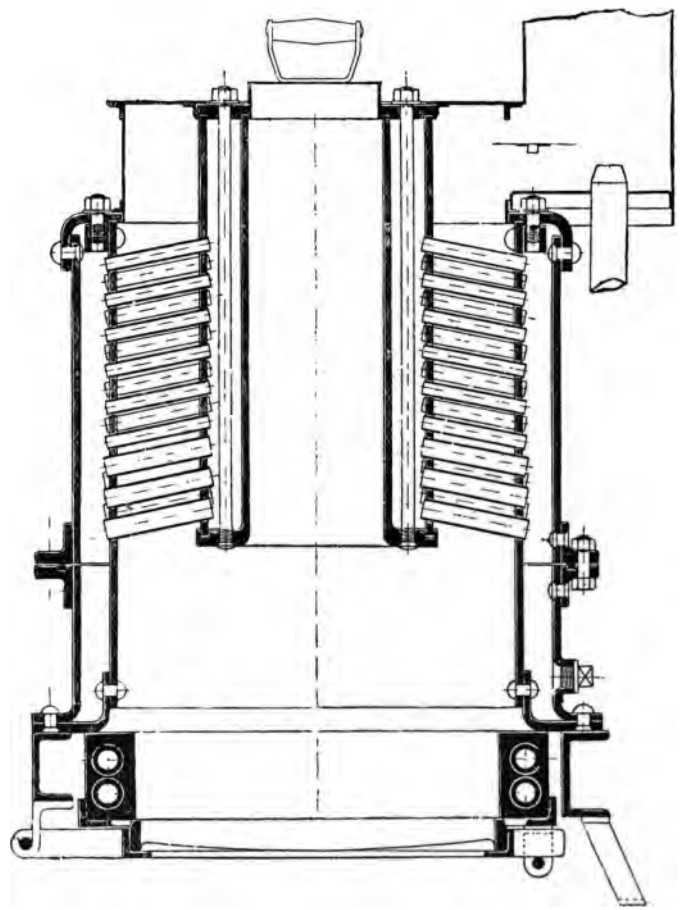

Fig. 88.—Straker heavy-freight steam vehicles. Vertical central section of boiler.

72 sq. ft., a total length of 12 ft., with 6 ft. width, inside measurement. A double bunker at the front of the vehicle is capable of holding sufficient fuel for a 6-hours' run, and a galvanized iron

tank holds a supply of 140 gallons of water, the usual fittings for lifting water being provided. The frame is of strong steel channel, well braced together with transverse channels, tee-irons, and angles.

The dimensions of the Straker 5-ton lorry are, approximately, 18 ft. in length by 6 ft. 6 ins. extreme width, with a wheel base of 10 ft., and a wheel gauge of 5 ft. 3 ins. from centre to centre. The maximum speed is 7 miles an hour, and it is capable of surmounting gradients up to 1 in 6 on ordinary roads, and of drawing a trailer carrying an additional load of 2 tons on level surfaces. The details of construction are practically the same as those of the covered waggon just described.

A 7-ton lorry is also made, which is identical in construction to the standard 5-ton lorry, with the exception that it is, of course, more solidly built throughout, and has an engine of 55 indicated horse-power.

The 2-ton van is fitted with a 25 indicated horse-power engine of high rotary speed and of relatively small dimensions, which is enclosed and lubricated on the splash system.

The Londonderry Heavy-freight Steam Vehicles

The standard type of heavy-freight steam vehicle, built by the Marquis of Londonderry at his works at Seaham Harbour, has come successfully through some very severe tests, one of the vehicles last summer having been run without stopping, with a full load of 5 tons, from Seaham Harbour to Whitehall, London, a distance of 294 miles, the time occupied in the journey being 54 hours.

The most noticeable features in this vehicle, the manufacture of which has been introduced into the Seaham Harbour Works by Mr. J. Donovan, the manager, are the arrangement of cast-steel side frame and the spur driving gear. With reference to the latter, it is stated that toothed wheels in the driving gear of some of these lorries have been run over 13,000 miles with practically no signs of wear. The engine is of the compound type, fitted with flat or locomotive slide-valves, and steam is generated in a fire-tube boiler.

During the above-mentioned trial the consumption of gas coke,

including that used in cleaning the fire at intervals, was 1 cwt. for every 11 miles run.

Fig. 89 shows a standard pattern of 5-ton Londonderry steam waggon, which is built to conform to the new regulations, the principal dimensions being 19 ft. in length over all, 6 ft. 6 ins. in width, and 8 ft. in height to the boiler chimney top. The carrying platform is 12 ft. 6 ins. by 6 ft. 3 ins., and is fitted with 18-in. sides, hinged to drop, or entirely removable, as required. This platform rests on the main frame, the latter being constructed of channel steel and strongly braced. When loaded, the height of the platform from the ground is 3 ft. 3 ins.

Fig. 89.—Londonderry heavy-freight steam vehicles. Standard 5-ton waggon.

The road wheels (Fig. 92) are of solid cast steel, no rivets or joints being employed in their construction, rear, 3 ft. 3 ins. diameter, with tyres 10·5 ins. in width, and front wheels 2 ft. 9 ins. diameter, with tyres 6 ins. wide. When preferred, the Londonderry patent composite wheels can be substituted for the above. These latter are cut from prime, well-seasoned teak, and are hooped with rolled steel rims and renewable protection tyres. The naves are of cast-steel, and the drive is transmitted to the peripheries by extended arms or naves. The main axle is 5 ins. diameter, and carried in axle boxes supported by heavy springs of finest quality steel.

The engine, which is shown in plan and vertical longitudinal

section in Figs. 90 and 91, is of the horizontal compound type, fitted with locomotive pattern slide valves. The high-pressure cylinder is 4·25 ins. diameter, and the low-pressure cylinder 6·75 ins. diameter, by a stroke of 7 ins. The valve motion is of the single eccentric type, with constant lead, and permitting cut-off at any desired point of stroke. The wearing surfaces are ample, and the whole engine is enclosed in an aluminium dust-proof casing. Provision is provided for working both cylinders

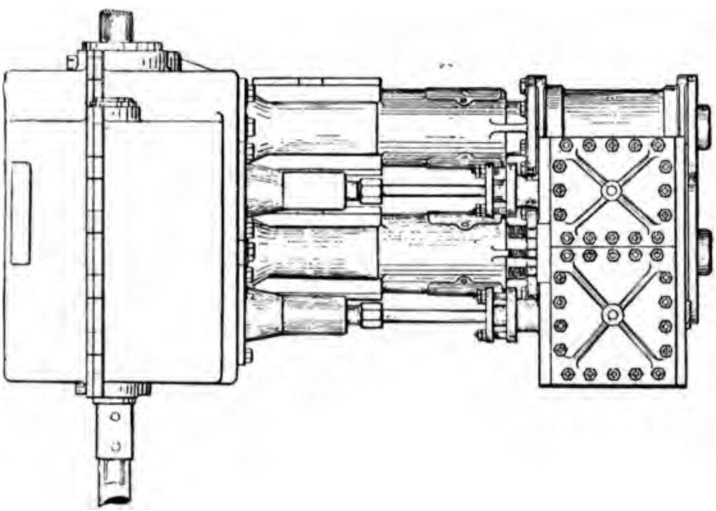

Fig. 90.—Londonderry heavy-freight steam vehicles. Plan view of engine.

with high-pressure steam when desired, and the engine is capable of taking the waggon fully loaded up a gradient of 1 in 8. The lubrication of the engine is partly on the splash principle, the slide valves and cylinders being oiled automatically by a positive feed pump lubricator.

The gearing is of steel throughout, the wheels on crank shaft and second shaft having machine-cut teeth, and all the bearings being thoroughly dust-proof. The construction admits of each separate part of the mechanism being taken adrift without disturbing the adjacent gear, and is, at the same time, as simple as possible. Fig. 92 shows the driving wheel and differential gear

on the main axle, which is of mild steel. The crank-shaft pinions slide on a machine-squared portion of shaft, and the driving pinion on the second shaft is securely fitted on a square portion

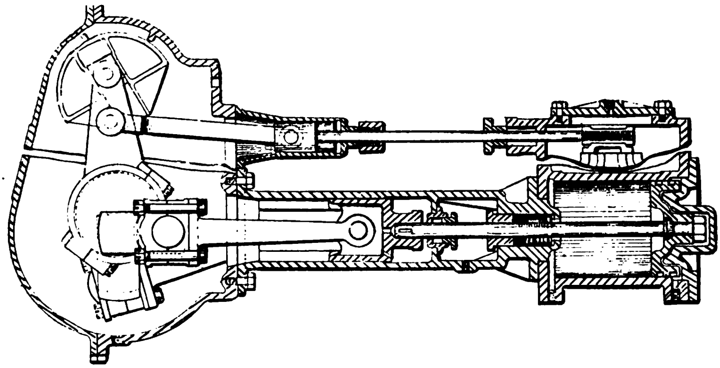

Fig. 91.—Londonderry heavy-freight steam vehicles. Longitudinal vertical section of engine.

of the latter. The crank shaft and second shaft are 2·25 ins. and 3 ins. diameter respectively, and are carried in swivel bearings. The lubrication of the axles and shafts is by grease lubricators.

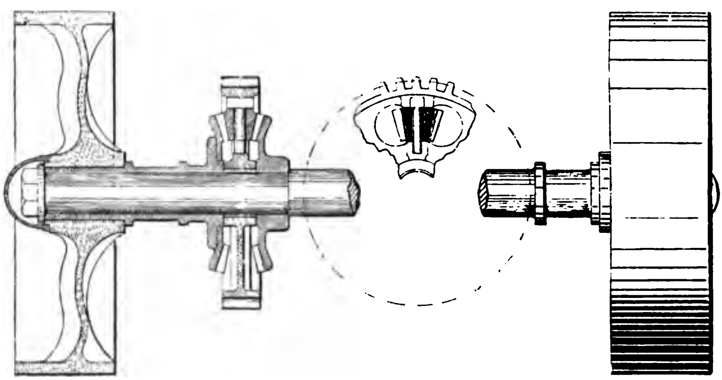

Fig. 92.—Londonderry heavy-freight steam vehicles. View showing driving wheel and differential gear on main axle.

A two-speed gearing is provided for hill climbing and ordinary road running, and change of speed is effected by a single lever,

within convenient reach of the driver. The low gear gives a speed of 2·5 miles an hour, and the high gear one of 5·5 miles an hour, to the vehicle.

The boiler, which is placed in front of the driver's seat, is of the fire-tube central-feed type, and is strongly built and certificated for a safe working pressure of 200 lbs. per square inch. The shell contains the firebox and central tube, which is also used for feeding the boiler with fuel. Attached to this central tube is the top tube plate, the fire tubes, which are $\frac{1}{8}$ in. thick and of the finest grade weldless steel, being expanded in the furnace crown and tube plate. There are four large cleaning doors, giving access to the firebox sides and tube plate, and wash-out and mud-hole doors are provided at the top and bottom of the shell. The boiler is fired from the top, and the firebars with ashpan can be raised or lowered by the driver, an arrangement which allows of the fire being cleaned out or relighted in three minutes.

To sweep out the fire tubes, all that is required is to disconnect the smoke box, to which is attached the chimney, the whole length of the tubes being then exposed. The ordinary working water level is 1 ft. 9 ins. above the firebox crown. The heating surface is 95 sq. ft., and the grate area 3·5 sq. ft. The boiler is fitted with all the necessary mountings of the best gun-metal.

An automatic feed pump, geared down from the crank shaft, and capable of being thrown out of gear for pumping purposes when the engine is standing, supplies the feed water, and an injector is fitted to feed independently when required. The temperature of the feed water is raised to about 180 degrees before entering the boiler by passing through a feed-water heater. Two side bunkers are provided for the fuel, which may consist of either coke or coal. The water tank holds a sufficient supply for an ordinary run of 25 miles under load, and a suitable water lifter is provided.

The steering is effected by a worm and quadrant, with only four working joints, ball bearings and ball socket joints being provided to facilitate the operation and counteract uneven motions on rough roads. There is a live fore axle, which gives the vehicle a three-point support.

A powerful screw brake acting through renewable shoes on the tyres of the main wheels is provided, and is capable of bringing the vehicle to a stand within 20 feet on the steepest

gradient. Another brake is formed by the reversing gear of the engine.

Ellis Heavy-freight Steam Vehicles

The standard type of heavy-freight steam vehicle built by Messrs. Jesse Ellis and Company, Limited, Maidstone, and

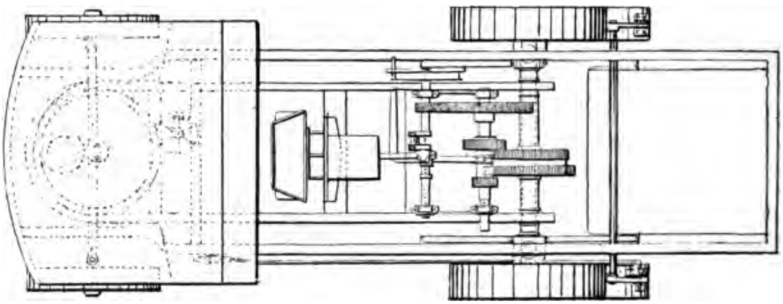

Fig. 93.—Ellis heavy-freight steam vehicles. Plan view of standard 5-ton waggon.

illustrated in Figs. 93 to 95, is adapted to carry 5 tons on body, or 4 tons on body and 2 tons by trailer.

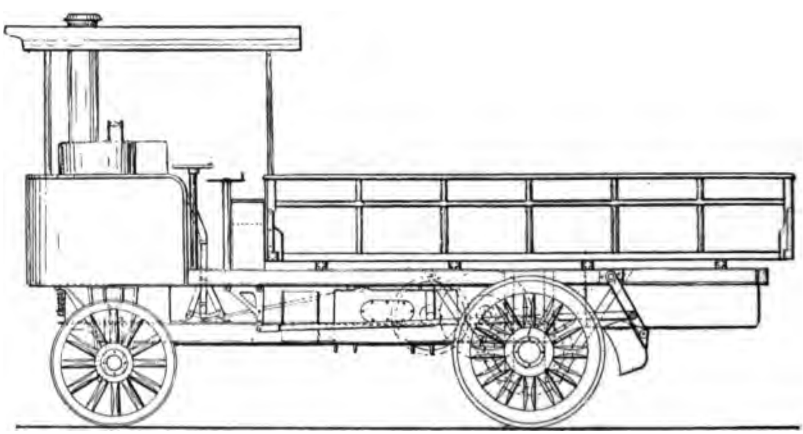

Fig. 94.—Ellis heavy-freight steam vehicles. Side elevation of standard 5-ton waggon.

The framing is of channel section mild steel, well braced and bracketed, and the engine, boiler, and gearing are mounted on an

auxiliary suspension frame connected to the front and hind axles in such a manner as to be independent of the body frame. The front, or steering, wheels are 36 ins. diameter, with 5-in. steel tyres $\frac{5}{8}$ in. thick. The rear, or driving, wheels, 42 ins. diameter, with 8-in. steel tyres 1 in. thick. Both front and rear wheels are of artillery pattern, and the steerage is on the Ackermann principle. The brakes comprise a band brake on engine flywheel, worked by a foot lever, and a hand-screw brake acting on both driving wheels.

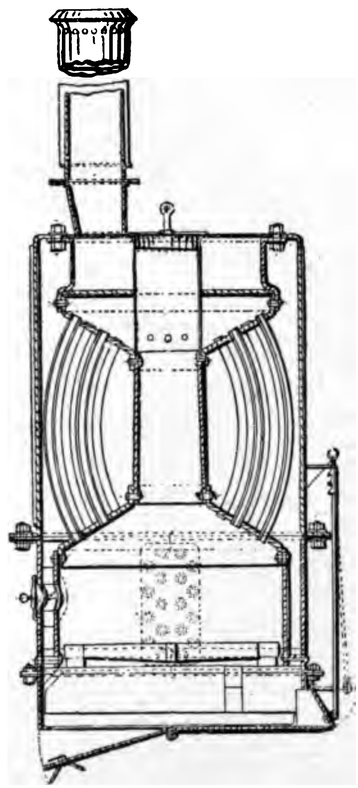

Fig. 95.—Ellis heavy-freight steam vehicles. Vertical central section of boiler.

The engine is of the horizontal compound reversing type, enclosed in a dust-proof, oil-tight casing, with top lid and side hand holes. A bye-pass valve admits high-pressure steam to both cylinders when desired.

The boiler (Fig. 95) is of the Ellis-Balmforth pattern, fired from top through a central flue, and with removable outer shell. The plates are mild steel, shell plate $\frac{3}{8}$ in. thick, fire-box plates $\frac{7}{16}$ in. thick, and tube plates $\frac{1}{2}$ in. thick. There are 119 solid cold-drawn steel tubes, $1\frac{1}{8}$ in. diameter and $\frac{1}{8}$ in. thick. The heating surface is 90 sq. ft., the grate area 3·5 sq. ft., the working pressure 290 lbs., the water capacity 460 lbs., and the efficiency is given as 8 lbs. of steam per lb. of coke, and 8 lbs. of steam per square foot of heating surface. The boiler is tested to 400 lbs. per square inch by hydraulic pressure. The dome is fixed by 43 $\frac{3}{4}$-in. bolts, 2-in. centres. There are two tanks, having a combined capacity of 150 gallons, one of which forms

the driver's seat, and the rear tank having a strainer. The water lifter is fitted with 30 ft. of $1\frac{1}{2}$-in. three-ply indiarubber suction hose, with strainer on end. The water supply is sufficient for 12 miles. The fuel bunkers are in front, and capable of holding sufficient fuel for an ordinary day's run of 12 hours.

The transmission is by means of steel toothed gearing. Double helical wheels on the first and second shaft connect by spur gear with the rear axle, the spurs being renewable by simply detaching the toothed rims and fixing others by helicoid spring nuts. There are two speeds, giving 6 and 3 miles per hour. Suitable compensating gear is provided, and the driving axle, which is of steel $3\frac{1}{2}$ ins. diameter by 6 ft. $3\frac{7}{8}$ ins. in length, is fitted with patent roller bearings.

The overall dimensions of the vehicle are: 16 ft. 6 ins. long; 9 ft. in height to top of funnel; 6 ft. 6 ins. wide; wheel base, 8 ft. 9 ins. The inside dimensions of the standard body are 9 ft. 3 ins. by 6 ft. 3 ins. by 3 ft. 3 ins., with a capacity of 7 cubic yards.

This lorry has been successfully subjected to very exhaustive tests.

Nayler Heavy-freight Steam Vehicles

Messrs. Nayler and Company, Limited, Hereford, build several patterns of steam waggons, presenting some novel features in design. The frame of the standard type of 5-ton lorry (Fig. 96) is formed of heavy steel channel, strongly braced together with T-iron gussets and angles, carefully riveted, the rivet holes being all drilled. The length of the body is 12 ft., and the width 6 ft. 6 ins., and a level platform or any other type of body can, of course, be adapted. The superficial area is 78 sq. ft.

The wheels are of the traction-engine type, the rear 3 ft. diameter by 7 ins. wide, the front 2 ft. 6 ins. diameter by 5 ins. wide. A double shoe brake, worked from the driver's seat, and bearing on the rear wheel tyres, is provided, and the link motion is also available for braking purposes.

The engine is of the compound horizontal reversing type, with cylinders 3·75 ins. and 6·75 ins. diameter, by 6 ins. stroke, with link motion reversing gear, and enclosed in a sheet-iron casing. The cylinders are well lagged, and covered with blue steel. The normal engine speed is 400 revolutions per minute

The boiler is of the fire-tube type, easily accessible for cleaning

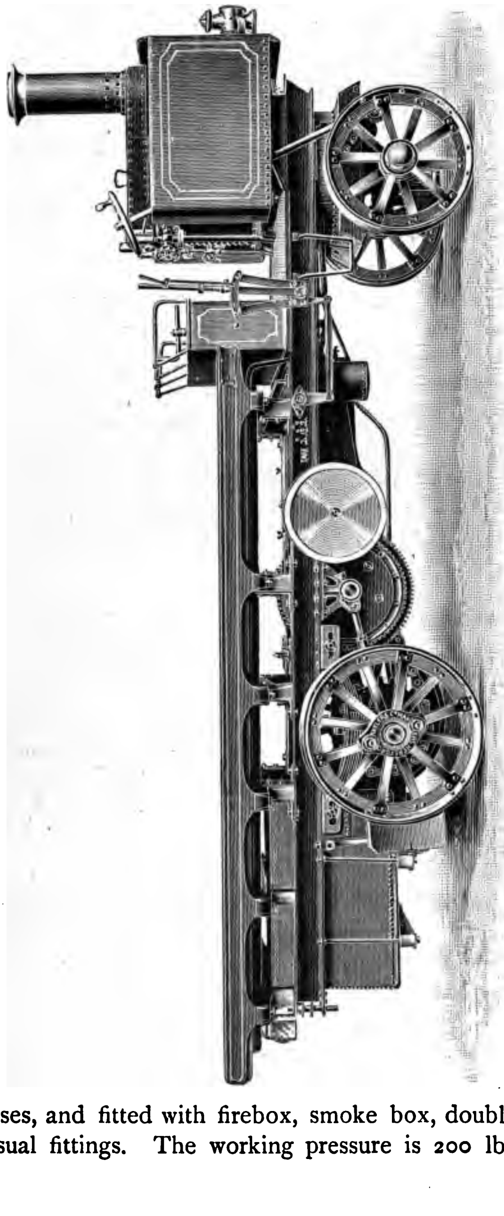

Fig. 96.—Nayler heavy-freight steam vehicles. Standard 5-ton waggon.

purposes, and fitted with firebox, smoke box, double funnel, and the usual fittings. The working pressure is 200 lbs. per square

inch. A 140-gallon water tank, provided with a filter, and a bunker with a fuel capacity for one day's work are provided.

The engine crank shaft is extended in square section, and carries a double pinion of the usual type, which can be thrown in and out of gear by means of a lever working in a quadrant, and the vehicle must be stopped to change the gear. These pinions mesh with gear wheels upon the second motion shaft, which is supported in long gun-metal bearings secured to the frame and carries the chain pinion. Motion is transmitted from the second motion shaft to the driving axle by a chain capable of standing a working strain of 20 tons.

The rear, or driving, axle is mounted in axle boxes bushed with gun-metal, and radius rods with screw adjustment are provided. It is of the best mild steel, and has a strong set of differential gearing with a locking arrangement. Coupling to the driving wheels is effected by special bolts and nuts in long gun-metal bearings fitted to the axle boxes and secured to the springs. The front axle is also of mild steel, and has a central turning pivot, thus providing a three-point support. Two speeds are provided, giving 2 and 6 miles an hour.

Robertson Heavy-freight Steam Vehicles

The standard type of 5-ton steam waggon or lorry shown in Fig. 97 is built by Messrs. James Robertson and Sons, Fleetwood, and has a total length of, approximately, 18 ft. 9 ins., with a width of 6 ft. 5 ins. over all. The wheel base is 9 ft., and the wheel gauge, centre to centre of tyres, is 5 ft. 8 ins. The lorry platform has a useful area of 78·5 sq. ft., the length being 13 ft. 4 ins. and the width 6 ft. 5 ins.

The rear portion of the vehicle is supported on strong laminated springs, the extremities of which work in steel shoes with hard brass liners.

The rear, or driving, axle is of rolled mild steel girder section with forged steel ends accurately machined and riveted, and held in position by radius rods secured to the steel pedestals of the second motion shaft. The fore part of the vehicle is carried by the front axle, which is guided by steel horn plates, and the weight is taken centrally by a powerful laminated spring, thus providing a three-point support.

The front axle is a mild-steel forging with long bearings and hardened pins. The wheels are of the artillery pattern, having ash felloes, oak spokes, and steel malleable naves, with hard gun-metal bushes, and steel tyres 6 ins. wide on front wheels, which are 2 ft. 9 ins. diameter, and 8 ins. wide on the back wheels, which are 3 ft. 3 ins. diameter. The steering is on the Ackermann principle, actuated by a vertical screw, and a brake operated from the driver's seat is provided in addition to the reversing lever.

The engine is of the horizontal compound reversing type, cylinders 4 ins. and 7 ins. diameter by 5 ins. stroke, running

Fig. 97.—Robertson heavy-freight steam vehicles. Standard 5-ton waggon.

normally at a speed of 435 revolutions per minute and developing 25 brake horse-power. It is enclosed in an oil-tight and dust-proof box. The crank shaft is of forged steel, with balanced cranks and eccentric sheaves solid therewith and all machined together. By moving the change-speed lever near the driver's seat to the central position, the engine can be run independently for boiler feeding purposes, and an auxiliary cock is provided for admitting live steam to the low-pressure cylinder when required.

The boiler, which is of the multitubular fire-tube design, presents some special features, and is shown in sectional plan and side elevation in Figs. 98 and 99. It is constructed of mild steel with seamless steel tubes, and is fired centrally. The coke bunkers

have a sufficient capacity for a run of about 30 miles. The working pressure is 200 lbs. per square inch, and it is tested to 400 lbs. per square inch by hydraulic pressure. The grate area is 2·6 sq. ft. and the heating surface 80 sq. ft. The tubes are fixed radially between the fire box and the outer shell, the latter being almost completely enclosed by an easily removable smoke-box casing. All the tubes

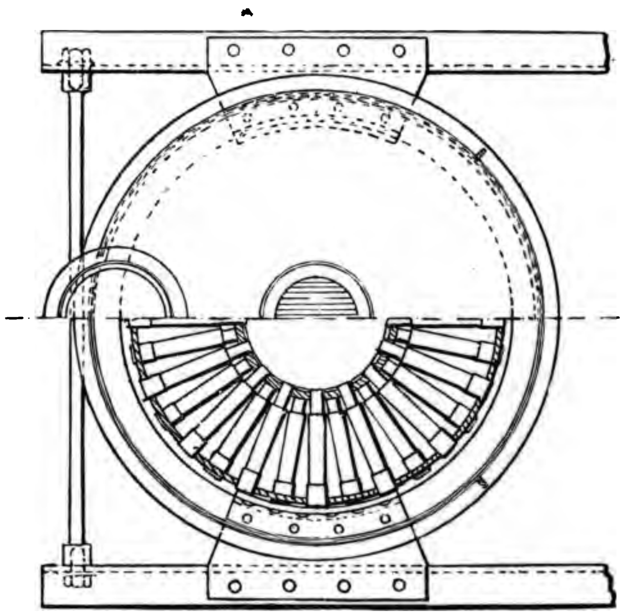

Fig. 98.—Robertson heavy-freight steam vehicles. Sectional plan of boiler.

are entirely under water. The fire bars with the ashpan are slung beneath the boiler.

A feed-water heater with aluminium body, brass-tube plates, and Row tubes, capable of heating the feed water to 190 degrees Fahr. is provided, the condensed steam being filtered and returned to the feed-water tank.

Both a main feed pump driven from crank shaft through gearing in the engine box or casing, and an auxiliary feed pump with separate steam and water connections are provided.

A square sectional extension is formed on the crank shaft,

upon which slides a double steel pinion of the usual type, operated by a lever to gear with the differential gearing on the second motion shaft. From this latter shaft motion is transmitted to the

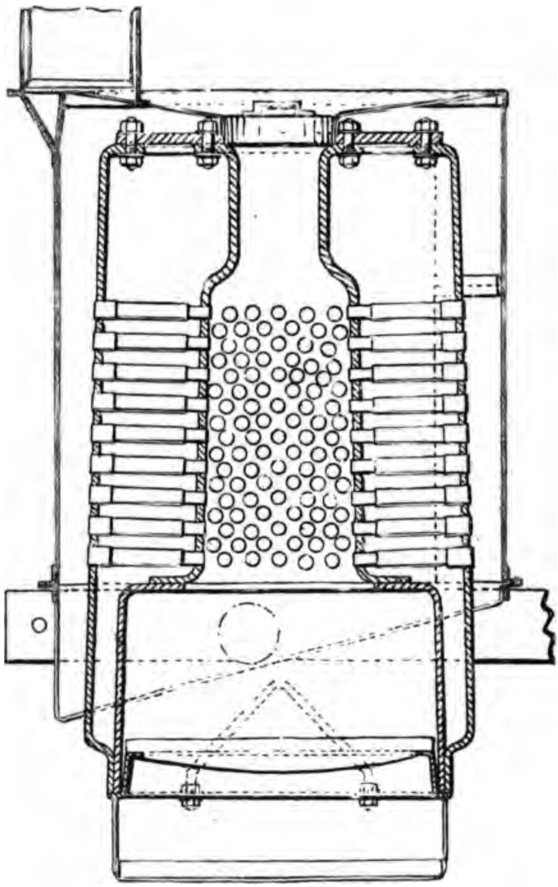

Fig. 99.—Robertson heavy-freight steam vehicles. Vertical central section of boiler.

driving wheels by sprocket or chain wheels at each end, gearing through large roller chains with hardened steel bushes, with large sprocket or chain wheels carried by steel brackets secured to the felloes of the driving wheels. A steel clutch moved into or out

of gear by a small steam cylinder operated from the footplate is provided for locking the differential gearing.

The Yorkshire Heavy-freight Steam Vehicles

Figs. 100 to 102 illustrate one of the standard 4-ton lorries built by the Yorkshire Patent Steam Waggon Company, Hunslet.

The framing of the vehicle is of substantial construction, being built of channel steel fixed to cast-steel cross girders and well braced with diagonal stays.

The wheels are of the artillery pattern, and the steering is on the Ackermann principle, operated by a screw and levers. A

Fig. 100.—The Yorkshire heavy-freight steam vehicles. Standard 4-ton lorry.

powerful screw brake, which acts directly upon the tyres of the driving wheels, is provided.

The design of the engine presents the distinctive feature of the cylinders being fixed outside the frame, the high pressure on one side, and the low pressure on the other. The crosshead runs in cylindrical guides with dust-proof covers, and the cranks and connecting rods are also enclosed in dust-proof metal casings and run in oil baths. A simple single eccentric reversing gear, having no open parts and operated from the driver's platform, is provided.

The boiler is of a special patented design, and is fixed across the frame at the front end, forming a very compact arrangement. As will be seen from the sectional view (Fig. 101), the boiler is of the locomotive type as regards the firebox, the principal difference being that there are two short barrels instead of one long one, and two sets of fire tubes connect the firebox with the chamber or

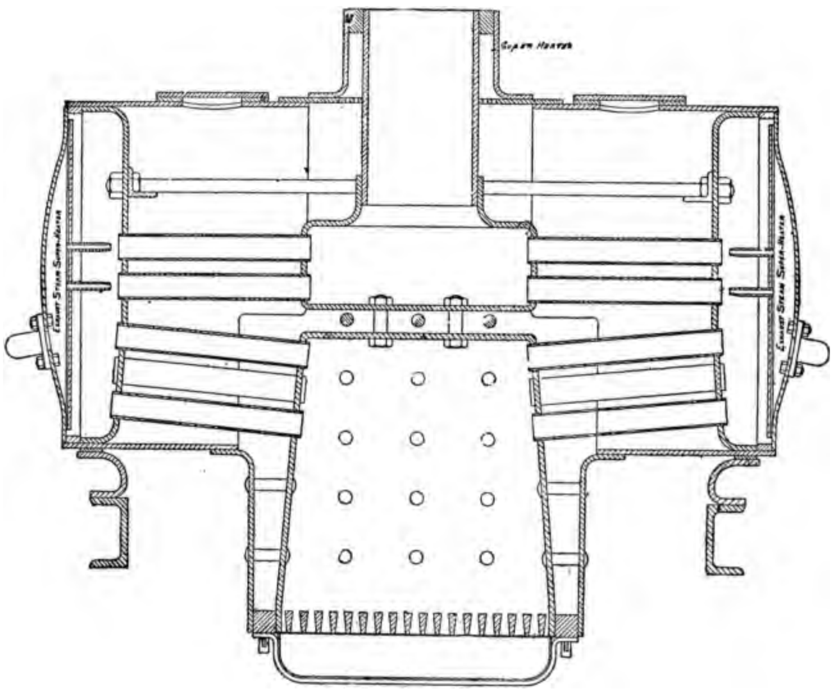

Fig. 101.—The Yorkshire heavy-freight steam vehicles. Vertical central section of boiler.

smoke boxes at the outer ends of the barrels, return tubes conducting the gases therefrom to another chamber above the firebox and at the base of the chimney. The exhaust steam is discharged into the smoke boxes, where it is thoroughly superheated and passes through a series of small jets into each of the return tubes. This arrangement is claimed to ensure both an invisible and silent exhaust, and also rapid steaming without the discharge of

sparks from the chimney. The boiler is fed by a large force pump worked from a second motion shaft, and an injector is also provided. The feed-water tank is placed at the rear of the vehicle, and a water lifter is fitted. All the tubes in the boiler are well below the normal water level.

The transmission is through spur gearing, and the arrangement is shown in the diagrammatical view, Fig. 102. The crank shaft is supported in two inverted pedestals secured to the frame, and to each of these pedestals a steel bracket is hinged, carrying the second motion shaft and the rear axle bearings, the other extremities of the brackets being free to slide on strong guides.

The frame is supported upon laminated springs attached by

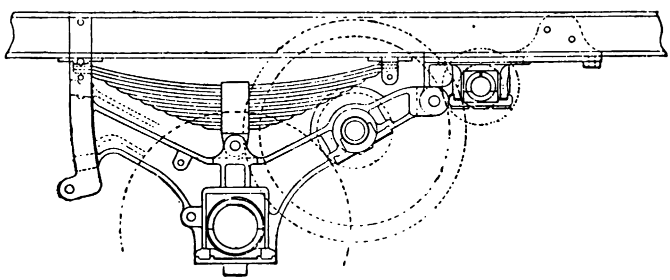

Fig. 102.—The Yorkshire heavy-freight steam vehicles. View of shaft and axle bracket.

joint pins to the brackets, so as to be capable of rising and falling without any material variation in the working centres of the shafts.

Each shaft has but two bearings, all the gearing being between them, and as the second motion shaft and rear axle are supported in swivel bearings, unequal loading or rough roads cannot cause binding of the shafts in the necks.

This vehicle, it is stated, can travel 40 miles per day under average conditions, with a consumption of from 3 to 4 cwts. of gas coke. With a load of 4 tons, and drawing a trailer with a load of 2 tons, the vehicle is said to be capable of ascending gradients of 1 in 10.

Gillett Heavy-freight Steam Vehicles

The standard steam-driven 3-ton waggon built by the Gillett Motor Company, Limited, Hounslow, has a channel frame, the

side pieces of which curve round in front and are joined centrally.

The front and rear axles are tied together by tubular stays fixed at the fore ends and hinged at the rear ends. Full elliptic springs support the fore part of the frame on the front axle, and semi-elliptic springs, each sliding in guides at one end, carry the rear. The hind wheels are 4 ft. in diameter, and the front wheels 3 ft. in diameter with steel tyres, the wheel base being 12 ft. The rear axle is a live one, and is supported by four bearings in a casting forming an oil-tight casing surrounding the crank shaft, the valve gear, the differential gear, and the toothed gearing driving the axle.

Powerful band brakes are fitted to the rear wheels. The weight of the vehicle unladen is about $2\frac{3}{4}$ tons.

The engine is of the horizontal compound type, with double-acting cylinders, 4 and 8 ins. diameter respectively by 6 ins. stroke.

These valves are of the piston type, and they are placed below the cylinders, and are operated by Joy valve gear, a special valve being provided for admitting live steam to the low-pressure cylinder when desired. The engine runs normally at 400 revolutions per minute, and lubrication is effected by a sight feed drop lubricator connected with the steam pipe.

The boiler is of the Gillett water-tube pattern, consisting essentially of a vertical cylindrical vessel, from which a large number (200) of $\frac{3}{4}$-in. steel tubes radiate outward and extend downwards to an annular water chamber. In addition to the above tubes, there are two large tubes forming a similar connection. The heating surface is about 100 sq. ft. The flue extends downwards and a steam blast gives the requisite draught, a hinged lid at the top being provided for opening when starting the boiler.

The feed water is supplied by an ordinary force pump, and an auxiliary Worthington steam pump is also provided.

The safety valve is set to blow off at 240 lbs. per square inch, and the normal working pressure is 220 lbs. per square inch.

Oil fuel is used, the burner being of the Gillett type, in which the pressure of the oil in the vaporizer automatically regulates the velocity of the oil issuing from the nozzle.

The oil storage tank, which is circular, has a capacity of 40 gallons, and is located inside a square water tank, the water

capacity being 30 gallons; a second 30-gallon water tank is also placed beneath the driver's seat.

The oil from the storage tank is pumped into a pressure tank, having a capacity of 2 gallons, against an air cushion, by a force pump, or by a hand pump near the driver, the pressure being afterwards maintained by the fuel pumps.

The normal pressure maintained is 80 lbs. per square inch, a relief valve on the delivery pipe preventing this being exceeded.

A small hand pump admits of the supply of air in the pressure tank to form the cushion, being renewed when necessary.

The oil feed to the burner is automatically controlled by a diaphragm acted upon by live steam and arranged to shut down when the pressure in the boiler reaches 220 lbs. per square inch. An arrangement is also provided for controlling the oil feed by hand.

The transmission comprises a toothed wheel or pinion mounted centrally on the crank shaft and gearing with a larger toothed wheel surrounding the differential gear. The drive from the axle is communicated to the felloes of each wheel by two carrier arms, which admit of a certain amount of play of the springs.

With a load of 3 tons the water consumption is stated to be about 3 gallons per mile, with a fuel consumption of about two-thirds of a gallon of oil per mile.

The Wantage Heavy-freight Steam Vehicles

The standard 4-ton steam lorry built by the Wantage Engineering Company, Limited, Wantage, is shown in Fig. 103. The underframe is constructed of channel steel stayed with cross channels and angle plates and riveted up throughout.

The front wheels are 2 ft. 10 ins. diameter, and the rear wheels 3 ft. 6 ins. diameter, with 4-in. tyres. They are of artillery pattern, with oak spokes, ash felloes, and steel naves bushed with hard gun-metal, and having weldless steel tyres.

The platform, which is entirely independent of the working parts and the main frame, measures 12 ft. 6 ins. by 6 ft. 5 ins., the space available for goods being 75 sq. ft.

The engine is of the horizontal compound reversing type, with cylinders 3·5 ins. and 6·25 ins. by 6 ins. stroke, running at 500 revolutions per minute. It is entirely cased in, but presents no special features of novelty.

The boiler is either of the water-tube or fire-tube type, having a removable external shell, a central firing chute for coke fuel, and a hinged ashpan, the latter, as also the cover of the firing chute, serving to regulate the fire. The working pressure is 225 lbs. per square inch. The boiler is normally fed by an automatic feed pump, having double check valves to suction and delivery, and driven by an eccentric from the compensating gear shaft. An auxiliary

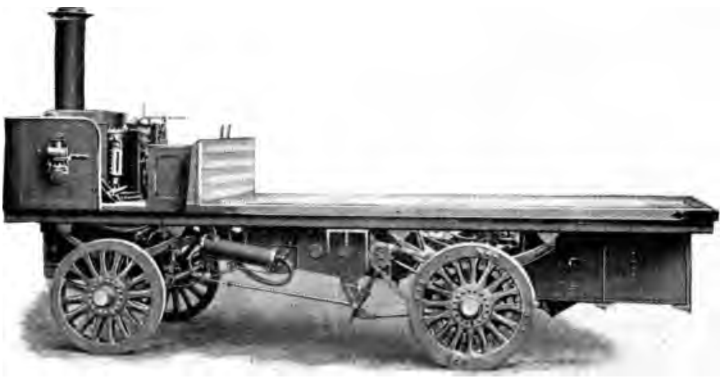

Fig. 103.—The Wantage heavy-freight steam vehicles. Standard 4-ton lorry.

steam pump is provided for use when the engine is standing. The feed-water tank has a capacity of 130 gallons.

Two changes of speed are given by the transmission gear, and the gear wheels are secured by bolts to turned-up flanges without keys. The compensating gear shaft is hollow, and a bolt passed through it takes the end thrust of the bevel wheels off the bearings. The drive is taken from the ends by roller chains to the felloes of the wheels. The compensating gear can be locked by an internal clutch arrangement operated by a lever beneath the frame.

The English Heavy-freight Steam Vehicles

The standard type of 5-ton lorry (Herschmann's system) built by the English Steam Waggon Company, of Hebden Bridge, Yorks, is shown in Fig. 104.

The main frame is of steel girder section, and the wheels

are of extra strong artillery pattern, rear 3 ft. 9 ins. diameter with 6-in. tyres, front 3 ft. diameter with 5-in. tyres. The platform measures 12 ft. in length by 6 ft. 6 ins. in width over all.

The engines are of the horizontal compound link reversing type, with cylinders 4 ins. and 7 ins. diameter by 9 ins. chute, covered by a sheet-steel casing, and fitted with controlling valve for admitting live steam to low-pressure cylinder.

The boiler is placed behind the driver's seat and front axle, and is of the fire-tube type, fired through a central shoot, and the top cover being made easily removable for cleaning purposes.

Fig. 104.—The English heavy-freight steam vehicles. Standard 5-ton lorry.

The working pressure is 200 lbs. per square inch, and the steam is superheated. The feed water is heated, and a steam pump and auxiliary injector are provided for boiler feeding purposes. The exhaust steam is passed through a reheating coil in the firebox.

The gearing is steel with machine-cut teeth, and provides for two speeds, viz. 3 and 6 miles per hour. The compensating gear has a patent self-locking arrangement actuated by a foot lever from the driver's seat. The drive consists of pinions swung from the stationary rear axle by radius links, and further connected to the waggon frame by links, which pinions mesh with internal gear rings attached to the road wheels. The result of this arrangement

is that, on starting the engine, the tendency of each pinion will be to mount upon the internally toothed gear wheels, which tendency, being resisted by the load on the vehicle, gives a substantial force against which to work as purchase at starting.

The steering gear is operated by a hand wheel on a vertical pillar through steel screws and levers, and the front axle is designed to give a bearing support close to both wheels, and to allow for inequalities of road surface. There is a brake acting on the rim

Fig. 105.—The English heavy-freight steam vehicles. Covered waggon.

of each gear ring attached to the driving wheels, besides that obtainable through the reversing gear, and the usual feed-water tank, coke bunkers, water lifter, etc., are provided.

Fig. 105 shows a covered waggon built by the same makers.

Mr. Herschmann, the designer of these vehicles, is the engineer to the Adams Express Company, New York, and president of the American Steam Waggon Company, and his heavy-freight vehicles have proved themselves most successful in the United States.

Other Heavy-freight Steam Vehicles

The typical examples of steam vehicles for heavy freight described in the previous pages must not be taken as being anything like complete; space, however, does not permit of even a

brief description of the many other excellent vehicles on the market, amongst which mention may be made of those built by Messrs. Bomford and Evershed, Limited, Pershore; E. S. Hindley and Sons, Bourton, Dorset; Edwin Foden, Sons and Company, Limited, Sandbach; Wm. Glover and Sons, Limited, Warwick; J. and F. Howard, Bedford; the St. Pancras Ironworks Company, Limited, King's Cross (the Hercules); and Atkinson and Phillipson (fitted with Towcord high-pressure boiler).

Many of the old firms of traction-engine makers who have not yet commenced to build steam motor vehicles are now making light steam motor traction engines adapted to work under the Light Locomotive Acts, for instance, Messrs. Aveling and Porter, Limited, Rochester; Wm. Fowler and Company, Limited, Lincoln; F. C. Southwell and Company, London; Wm. Tasker and Sons, Limited, Andover; Wallis and Stevens, Basingstoke, etc.

CHAPTER VIII

HEAVY-FREIGHT VEHICLES (Continued)

Heavy-freight Internal Combustion or Explosion Engine Vehicles—General Observations—Examples of Heavy-freight Petrol Engine Vehicles—Heavy-freight Petroleum or Heavy Oil Engine Vehicles—Heavy-freight Petrol-electric Vehicles.

HEAVY-FREIGHT INTERNAL COMBUSTION OR EXPLOSION ENGINE VEHICLES

General Observations

As has been already mentioned in the commencement of the preceding chapter, recent improvements have enabled heavy-freight vehicles driven by internal combustion engines with carrying capacities of 5 tons and over to be successfully constructed, and it is acknowledged that the internal combustion engine offers many advantages for the purpose. One important advantage possessed by this type of motor is that the propelling mechanism is considerably (some 50 per cent.) lighter, and the available platform area is greater by some 25 per cent., than in the case of a steam engine with its steam generator, fuel bunkers, etc., and, besides, the delay and difficulty of obtaining water during the journey suitable for boiler feeding purposes, or, indeed, frequently water of any description at all, is obviated. Theoretically at least, moreover, the internal combustion engine is the most economical method of producing power yet known. The compact nature of the fuel used, its economical consumption, and its general high efficiency, place this type of engine in a high place as a prime mover. For with its many good qualities the steam engine must, nevertheless, always be theoretically a more expensive means of producing power than the internal combustion engine, inasmuch as the principle on which it works necessarily entails

the production of steam as an elastic medium from the non-elastic substance water, at a great cost in fuel.

The chief objections to internal combustion engines as prime movers have been already dealt with (see *ante*, pp. 4, 5), and need not be again alluded to. It may be remarked, however, that one of them, viz. the danger inseparable from the use of a light spirit or essence such as that commonly known as "petrol," which readily evaporates at ordinary temperatures, and is highly inflammable, can be obviated by the use as a prime mover of internal combustion engines adapted to consume as fuel heavy oils, such as ordinary petroleum lamp oils, which, besides imparting greater safety, would create a large saving in running expenses, as the latter are some 50 per cent. cheaper per unit measure.

The chief difficulty experienced in applying heavy-oil fuel to an internal combustion engine for motor vehicle work has been the imperfect combustion of the hydro-carbon fuel when the engine is working against a varying load or amount of work, as must be the case in traction on common roads. Once this imperfect combustion has been satisfactorily dealt with, however, there can be no doubt as to the superiority of the heavy-oil engine. Owing to "petrol" evaporating very readily, it is easily evaporated in its entirety, whilst the heavier petroleums have a tendency to immediately condense and resume their liquid form. This is of less importance in the case of stationary engines, in which the regular speeds at which they are run, and the even loads, reduces the difficulty of imperfect combustion to a minimum, and where, moreover, long exhaust pipes can be used to carry away the fumes. In the case of motor vehicles, however, as already observed, the above regular conditions are not practicable, and, moreover, offensive emanations due to imperfect combustion are inadmissible.

Much has been done to overcome the objections to the internal combustion engine as a motor for road vehicles. Its simplicity is a great point in its favour, and its economical running. These features have enabled it to compete more or less successfully with the steam engine, even in the case of heavy-freight vehicles, although the characteristics of the latter are silence and elasticity, whilst those of the former are noise and inelasticity.

EXAMPLES OF HEAVY-FREIGHT PETROL ENGINE VEHICLES

Milnes-Daimler Heavy-Freight Petrol Vehicles

Fig. 106 illustrates a type of 2-ton petrol lorry built by Messrs. Milnes-Daimler, Limited. The length of the vehicle is 16 ft. 11 ins. by 6 ft. 5 ins. wide, the wheel base 10 ft. 11 ins., and the floor space 9 ft. 6 ins. The frame is constructed of channel steel, and is capable of bearing a total dead load of 2½ tons. The diameter of the rear wheels is 3 ft. 5½ ins., and that of the front wheels is 2 ft. 7½ ins. by 4 ins. wide.

The motor is a two-cylinder light hydro-carbon engine, cylinder 105 mms. (about 4⅛ ins.) and stroke 130 mms. (about 5⅛ ins.), built on the Daimler principle and having the Daimler float feed, throttle, and patent water cooler of the marine condenser pattern. Automatic pressure lubrication is provided to all the bearings, and a gear-driven rotary pump circulates the cooling water. A portion of the exhaust is utilized to provide pressure for feeding the petrol, and ignition is on the Simms-Bosch magneto-electric system. The engine runs at 800 revolutions per minute and develops 9·7 brake horse-power.

Single friction cone transmission on the Daimler system is employed, and motion is transmitted from the main longitudinal shaft through differential gear on the Counstatt principle, two pinions meshing with two internally toothed wheels or rings fixed to the rear wheels. Speed-changing gear on the Counstatt principle, giving speeds of 1½, 3½, 6, and 8 miles an hour, is provided. In this type of gear one lever controls the first and second, and the third and fourth speeds, so that the two couples of speeds being independent of each other, when changing, neither of the couples affect the other set of gear wheels. For reversing, a special toothed wheel giving a speed of four miles an hour is brought into gear. There are two circumferential brakes acting on the rear wheels, and operated through worm gearing by hand from the driver's seat, a double-acting brake-clutch on the first speed shaft and a scrag on the rear axle.

Fig. 106.—Milnes-Daimler heavy-freight petrol vehicles. 2-ton covered waggon.

Delahaye Heavy-freight Petrol Vehicles

Another 2-ton petrol lorry is shown in Fig. 107. This vehicle is built on the well-known Delahaye system. The lorry has falling sides and back. The characteristic features of the system are the single belt transmission and the horizontal type of engine employed. This type of drive is claimed to be both thoroughly

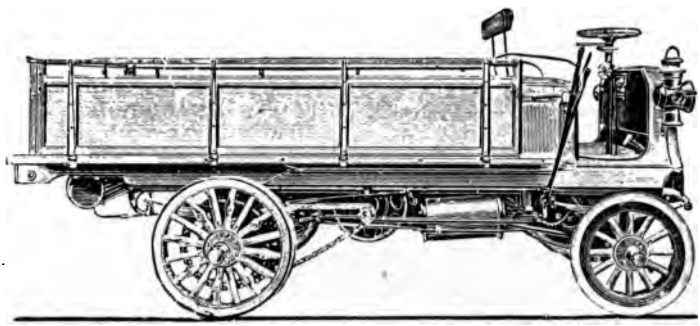

Fig. 107.—Delahaye heavy-freight petrol vehicles. 2-ton lorry.

reliable and to couple very gently, thus avoiding in a great measure the wear and tear due to shocks and jars experienced with ordinary coupling devices when carelessly handled. Three forward speeds and a reverse are provided, which admit of the driver regulating the speed up to a maximum of 12 miles an hour, at which rate the vehicle is capable of travelling loaded on fairly level roads.

Hagen Heavy-freight Petrol Vehicles

These vehicles are built in standard types with 2 and 3 tons capacities and capable of hauling a trailer.

The frame of the vehicle is constructed of channel steel, stiffened with wood and steel plates. The front springs are double elliptic, the axle working on massive horn plates. The rear axle has an ordinary single long elliptic spring.

The wheels are artillery pattern, front 3 ft. 3 ins. and rear 4 ft. diameter. Steering consists of pinion and spur gear acting through a spur quadrant on an Ackermann axle. The available platform area is $58\frac{1}{2}$ sq. ft.

The engine is of the horizontal single cylinder type, and develops 7 brake horse-power at 450 revolutions per minute. The cylinder is cast with its water jacket, and is attached by four studs to a main frame formed of a steel casting. The inlet valve is placed over the exhaust valve and is operated automatically by the suction of the piston; the exhaust valve is opened by a rocking lever, and both valves are located inside the combustion chamber.

The ignition is magneto-electric, the magneto spindle working directly on the ignition plug, and timed from the driver's seat. A belt-driven centrifugal pump is provided for circulating the cooling water, only six gallons of which are carried, the consumption being stated to be under half a gallon per ten hours' work.

The transmission gear comprises a crank disc at the end of the shaft, to which is fitted a connecting rod actuating a swinging lever with a fixed stroke. This swinging lever is placed parallel to and alongside another swinging lever pivoted in the centre and having rods at the top and bottom. The motion is imparted to this second double-ended lever by a connecting block, capable of sliding up and down, and according to its position the stroke of this second lever is varied between nothing and maximum. This motion of the lever is transmitted to the hind axle by two connecting rods, and the reciprocating motion is here converted to a rotary motion by means of positive friction mechanism. These friction discs are massive and run in oil. Alongside this gear box on the hind axle is a reversing gear, connecting with the transmission, so that any speed from zero to maximum in either direction can be obtained. The actual transmission is free from gear wheels, chains, belts, and clutches, and at all times the engine is working at maximum power.

The silencer consists of a very large exhaust box fitted with concentric mufflers, and a small exhaust for the waste gases.

Powerful brakes are provided, one acting on a band 6 ins. wide outside the differential is operated through a pedal lever, and the other is worked by a locking lever on the rear wheels.

The Orion (Swiss) Heavy-freight Petrol Vehicles

Petrol lorries of various sizes are built on this system. The following is a brief description of a vehicle of 2 to 3 tons capacity.

The frame is constructed of channel steel, and the petro engine, which is of the single-cylinder horizontal type, is located in the fore part of the vehicle. The engine is of 12 horse-power, and is adapted to run at a normal speed of about 700 revolutions per minute. Ignition is effected by means of a magnet, and there is pump-water circulation, and a fan-cooled radiator. There are four speeds forward and a reverse, and motion is transmitted from the engine to the gear box by a Renold silent chain, the gear box being in turn coupled to the driving wheels by side chains. The wheels are fitted with 6-in. solid indiarubber tyres.

During a practical trial of one of these lorries, in 10 days, 105 tons of coal were carried in 2 and $2\frac{1}{2}$ ton loads, on a consumption of 57 gallons of petrol, the vehicle negotiating, fully loaded, all the principal hills in the London district. A trial trip made by the lorry to Hatfield and back (20 miles each way), with over 2 tons of sand in bags, was performed in about $3\frac{1}{2}$ hours without a stop, and the consumption of petrol for the entire double journey of about 40 miles, loaded each way, was 10 gallons.

Cadogan Heavy-freight Petrol Vehicles

The petrol lorry shown in Fig. 108 is built by the Cadogan Garage and Motor Company, Limited, London, and is intended to carry a load of from 5 to 6 tons and to draw a trailer with a load of about 3 tons. The over-all measurement is 16 ft. by 6 ft.; wheel base, 9 ft. by 5 ft. 6 ins.; effective platform, 11 ft. 6 ins. by 6 ft.; and the weight when unladen, $2\frac{1}{2}$ tons.

The frame of the lorry is constructed of oak, and the engine frame of channel steel and well stayed. The body of the vehicle is supported on the axle by long springs, the front ones having indiarubber cushions between the springs, and the dumb irons, which arrangement is claimed to give great resiliency and freedom from vibratory shocks.

The wheels are of artillery pattern, with oak spokes and felloes, steel hubs and tyres, and are 3 ft. in diameter by $6\frac{1}{2}$ ins. on face. The chain rings are of forged steel, and are fixed by steel bolts and nuts to each spoke.

The motive power is derived from a two-cylinder Gobron-Brillic type of petrol engine, shown in Figs. 109 and 110, developing 34 brake horse-power. Each cylinder is water jacketed and

has two pistons, and the explosion takes place between them, thereby imparting one impulse to every revolution. The inlet

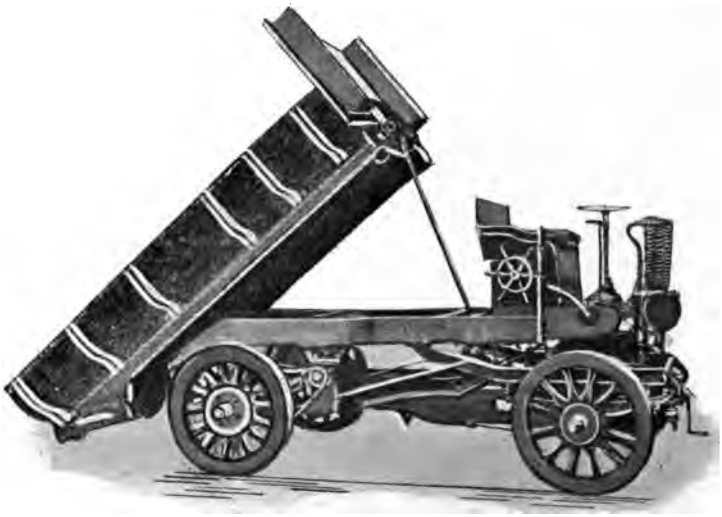

Fig. 108.—Cadogan heavy-freight petrol vehicles. 5 to 6-ton lorry with tipping body.

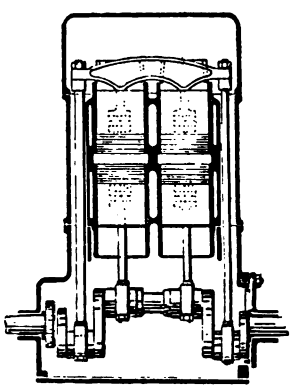

Fig. 109.—Cadogan heavy-freight petrol vehicles. Vertical longitudinal section of engine.

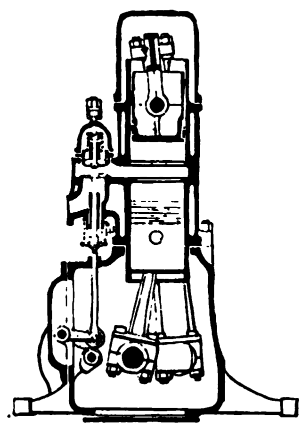

Fig. 110.—Cadogan heavy-freight petrol vehicles. Transverse section of engine.

valves are above the exhaust valves and are automatic and accessible by removing one nut. The ignition, controlled by a Bowdon wire affixed to steering column, is of the high-tension kind, with a 4-volt accumulator, high-speed trembler coil, and readily accessible commutator on the front part of the engine.

The carburettor, which is shown in section in Fig. 111, is of

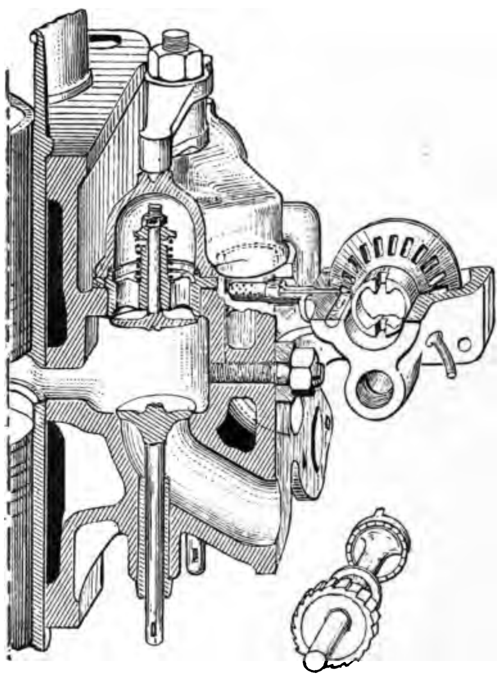

Fig. 111.—Cadogan heavy-freight petrol vehicles. Sectional view of carburettor.

the positive feed type, and is supplied by a rotating truncated cone having a series of recesses or pockets to receive the petrol, which are emptied one at a time into a perforated cylinder, from whence the petrol passes to the mixing chamber, and thence through the valve chamber into the cylinders, where the explosion takes place between the pistons and gives two impulses, one to each piston in the cylinder.

The arrangement for transmitting the impulse to the crank

shaft is clearly shown in Figs. 109 and 110, and all the gearing is cut out of nickel steel hardened, and enclosed in a dust-proof and oil-tight aluminium casing. Chain transmission is provided to each driving wheel, the chain wheels having a good ground clearance. The drive from crank shaft is through a gearing box on an intermediate shaft, having speeds of approximately $1\frac{3}{4}$, $3\frac{1}{2}$, 6, and 10 miles an hour, with load, each speed being increased 50 per cent. when empty. The change of speed is operated from the driver's seat by a single lever. The water circulation is by pump, and the radiator, being located in front, requires no fan.

There are two metal-to-metal brakes, a water-cooled foot brake on the differential shaft capable of causing the wheels to skid, and a hand brake on the travelling wheels. The chain is a 2-in. pitch roller. The sprocket bracket is of forged steel. An efficient exhaust silencer is provided. Gradients of 1 in 4 on an unmetalled road with a 5-ton load have been easily negotiated when in a muddy condition. The cost of fuel and lubricating oil is given as 0·3*d*. per ton-mile.

Stirling Heavy-freight Petrol Vehicles

A good example of the heavy-freight petrol vehicles designed and constructed by the Stirling Motor Construction Company, Granton Harbour, is a military waggon capable of carrying a load of 3 tons on the roughest possible ground, such as would have to be passed over during a campaign. As will be readily understood, the chief aim has been to avoid all complications, and to secure the greatest possible simplicity and compactness of construction, combined with the maximum of strength.

The total length of the vehicle, which is shown in Fig. 112, is only 16 ft., with a width of $6\frac{1}{2}$ ft. over the hubs, and a wheel base of 9 ft. The seat for the driver, being placed over the mechanism, allows of a good view being obtained ahead, and permits of the length of the vehicle being reduced. The body is 10 ft. 6 ins. long by 4 ft. 3 ins. in width. The driving wheels are 3 ft. in diameter, with 9-in. steel tyres, and the steering wheels have $7\frac{1}{2}$-in. steel tyres.

The motive power is provided by a four-cylinder petrol engine, developing fully 24 brake horse-power at about 800 revolutions per minute. The inlet valves are operated mechanically, and the

cylinder heads are solid. In addition to the magneto, high-tension electric ignition, with accumulators, is provided.

The power is transmitted by a large metal friction clutch to change-speed gears giving three speeds, and enclosed in an air-tight oil bath. The rear wheels are driven by a shaft, fitted with universal or Cardan joints, from a bevel pinion driving a counter-shaft fitted with steel toothed wheels meshing with driving rings constructed of special metal, and fixed to the inside of the wheels. The brakes comprise a foot brake working on a water-cooled drum on the shaft, and a powerful hand-lever brake operating a system of internal expansion blocks inside the driving rings on the rear wheels.

Wheel steering is provided with a special buffer spring to

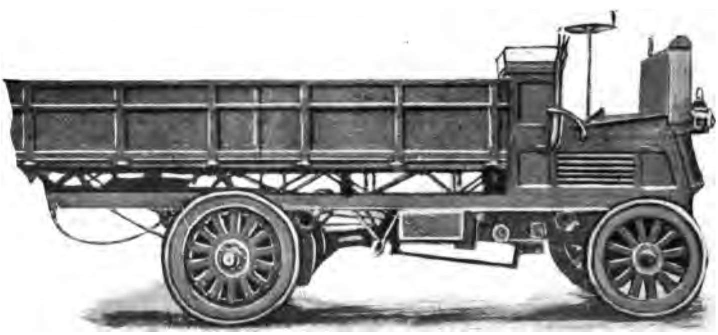

Fig. 112.—Stirling heavy-freight petrol vehicles. 3-ton military pattern waggon.

absorb shocks when passing over obstructions. No circulating pumps are used, the cooling water being circulated naturally.

A special feature is the provision of a large winding drum close to the rear axle, fitted with a long steel cable, and so arranged that by a movement of a hand lever the drum can be geared to the engine, and if the vehicle is itself anchored, it can be used as a windlass to haul other vehicles out of difficulties. By attaching the rope to an anchor or any available point, moreover, the winding drum or windlass can be used to haul the vehicle itself out of difficulty. Spuds or paddle blades are also provided, which can be bolted on the rear wheels, and enable soft ground to be readily crossed.

This lorry was successfully subjected to very severe tests with a total load of 7 tons.

Benz Heavy-freight Petrol Vehicles

Petrol lorries are constructed on the well-known Benz system (see Fig. 60, p. 150), to carry maximum loads of 1 ton 5 cwts., 2 tons 10 cwts., and 5 tons.

These lorries are: the first, 11 ft. 10 ins. long over all, 5 ft. 3 ins. wide, 6 ft. 5 ins. high; and platform, 8 ft. 2½ ins. in length by 4 ft. 11 ins. wide; the second, 13 ft. 9½ ins. long over all, 5 ft. 3 ins. wide, 6 ft. 5 ins. high; and platform, 10 ft. 3 ins. in length by 4 ft. 11 ins. wide; and the third, 14 ft. 10 ins. long over all, 5 ft. 3 ins. wide, 6 ft. 5 ins. high; and platform, 11 ft. 3 ins. in length by 4 ft. 11 ins. wide. The platform in each case is 3 ft. 5 ins. high from the ground level.

The wheels are of artillery pattern, very strongly made, and fitted with Kelly solid indiarubber tyres in the case of the 25-cwt. lorry, and with either steel or solid indiarubber in that of the larger ones.

The motors, which are of the horizontal two-cylinder Benz type, are respectively 6, 10, and 15 horse-power.

The vehicles are gear-driven with single belt, four speeds being provided besides a reverse motion. They have also each a suitable radiator and circulating pump, and a central lubricator.

The tares of these lorries are respectively 22 cwts., 28 cwts., and 2 tons. The maximum speed, when loaded, on the level is 10 miles an hour, and gradients of 10 per cent. can be ascended.

Frick Heavy-freight Petrol Vehicles

Petrol vehicles on the Frick system are built by Messrs. Dougill's Engineering, Limited, Leeds, adapted to carry loads from 10 cwts. up to 5 tons, the small sizes having single-cylinder engines of 9-horse-power nominal, and the larger sizes two-cylinder engines of 14-horse-power nominal, three-cylinder engines of 20-horse-power nominal, and four-cylinder engines of 28-horse-power nominal.

The length of the platform of the 30-cwt. lorry is 9 ft. 6 ins., and the breadth 5 ft. 3 ins. The wheel track is 4 ft.

6 ins. The framing is of steel channel, strongly stayed; the wheels of artillery pattern, 30 ins. diameter, with iron tyres. The engine cylinder is $5\frac{1}{2}$-in. bore by 6-in. stroke, completely water jacketed, and the engine runs at 800 revolutions per minute. The exhaust valves are of the mechanical pattern, and a rotary governor is provided. The bed plate is bolted direct to the main frame, and the engine, curburettor, and magneto, or sparking plugs, are enclosed in a bonnet. The single-cylinder engine is fitted with a rotary magneto, and the curburettor is of the float feed type. The front axle is solid forged steel with swivel ends, and the rear axle is of the live pattern, running in ball bearings, and fitted with differential gear running in an oil-tight case, and having a brake drum for a foot actuated brake.

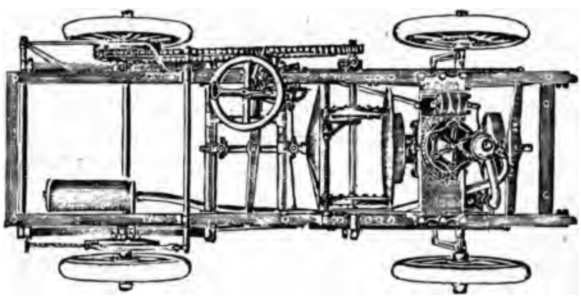

Fig. 113.—Frick heavy-freight petrol vehicles. Plan of frame and running gear.

Long laminated steel springs are provided for supporting the body.

The cooling is by a multitubular radiator with fan and circulating pump, and a duplicate connection for gravity circulation is also fitted.

The transmission is by a special patent variable friction gear, the construction of which is shown in the plan view, Fig. 113. It consists essentially of two friction wheels or discs, mounted on a countershaft, the first disc being the actual working disc, and the latter a dummy disc, merely serving to increase the friction surface. The working disc is so mounted upon the countershaft as to be capable of being moved or adjusted in the direction of its axis, so as to attain the different degrees of speed required,

the dummy disc transmitting the power from the disc-shaped fly-wheel through a counter disc to the first or actual working disc or wheel. The fly-wheel and counter disc can be moved in the direction of their axes, so as to be brought into contact with the friction wheels or discs, and thereby impart motion to the latter; and there is a chain drive from the countershaft to the differential gear on the rear axle.

The contact between the fly-wheel and the friction-wheel disc, and consequently the motion of the vehicle, can only take place when a hand lever provided for the purpose is slightly drawn. When the friction wheel is near the centre of the fly-wheel disc, that is to say, at the lowest speed, it is stated that the vehicle can ascend gradients up to 30 per cent.

Other Heavy-freight Petrol Vehicles

Amongst other heavy-freight petrol vehicles, those of the following makers may be cited: The Maudslay Motor Company standard 5-ton lorry; Crossley Leyland lorries; Wolseley lorries; Straker and Squire lorries; and the N.A.G. Automobile Company, Limited, standard 3-ton lorry.

Allsop Heavy-freight Petroleum or Heavy Oil Engine Vehicles

The characteristic feature of this system is that the motive power is derived from an engine adapted to use ordinary petroleum or lamp oil, and as the engine in question is practically smokeless, it is a type of motor particularly suitable for the propulsion of heavy and other freight vehicles.

This engine, which is shown in Figs. 114 to 117, has been designed, and patented both in this country and abroad, by Mr. R. Owen Allsop, Orpington, Kent, who has devoted many years to the solution of the problem of constructing an internal combustion engine adapted for the use of heavy petroleum oils.

The main distinctive features of the Allsop engine is the provision of a small auxiliary cylinder, which may be termed a vapour pump or carburettor, and the piston working in which is connected to a crank on the main shaft, set at an angle of 180 degrees relatively to the main or driving crank. The function of

this small cylinder or pump is to draw in, vaporize, compress, and measure the charge, which latter is then delivered to the larger cylinder, in which, after mixture with the necessary additional amount of air, it is exploded.

The engine shown is of the single-cylinder vertical type, and the construction will be readily understood from the illustrations. The two, three, and four cylinder engines are operated on the same principle, differing only in details of construction.

The small auxiliary cylinder or pump is located on the left-hand side of the main cylinder, and the following is the complete cycle of operations.

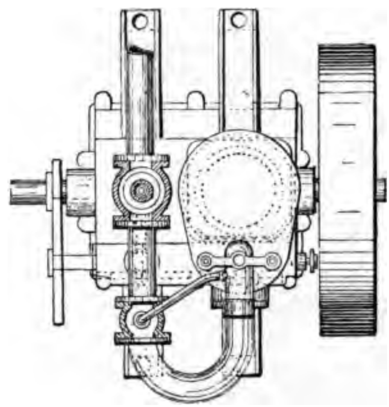

Fig. 114.—Allsop heavy-freight petroleum vehicles. Plan view of engine.

During the outward or suction stroke of the above pump, the requisite charge of oil, together with a small quantity of air, is sucked in through the oil supply inlet and air inlet, passing through the inlet valve, which is governed by a suitably adjustable spring. The oil is sprayed into a conical or funnel-shaped passage surrounded by a casing, and the exhaust or waste gases are passed into this casing before being allowed to escape into the atmosphere. These gases thus serve to heat and partially vaporize the entering oil, this operation being completed on the return stroke of the pump piston or plunger by reason of the heat of the adiabatic compression stroke added to the heat of the parts. On the next outward stroke of the pump piston or plunger, the vaporized oil is permitted to expand, and on the fourth or second return, or inward stroke, the gas or vapour is forced to pass through a non-return valve shown in Fig. 117, and a pipe which likewise passes through a box or casing surrounding a portion of same, and in which box or casing the exhaust is likewise permitted to circulate, and the gas or vapour is thus superheated on its way to the main or working cylinder.

During the inward movement of the pump piston or plunger,

the working piston makes an outward stroke, thus forming a partial vacuum, which serves to draw in through an air inlet the necessary additional supply of air to support combustion, which air is mixed with the oil vapour before entering the working cylinder.

On the return stroke of the working piston, the charge is compressed and ignited, and, by reason of the expansion taking place, the piston is forced outwards, forming the third stroke.

On the fourth or final inward stroke of the piston, the waste products of combustion are discharged through the exhaust in the usual manner; thus it will be seen completing the ordinary "Otto" cycle.

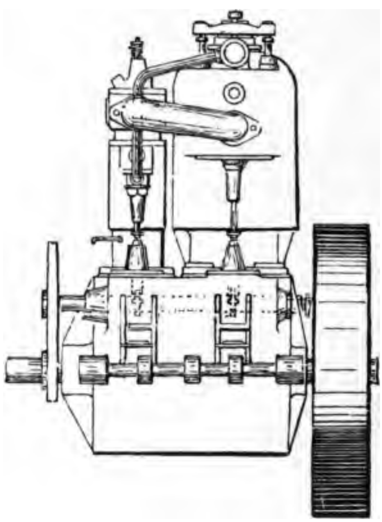

Fig. 115.—**Allsop heavy-freight petroleum vehicles. Elevation of engine.**

Electric ignition, comprising a commutator with brush contact, sparking plug, starting handle, etc., is provided, and a very important feature in the motor under consideration is that, owing to there being practically no condensation in the working cylinder, high-tension electric ignition with a single sparking plug can be used with equal certainty and regularity of firing with heavy petroleum oils to that obtainable with tube ignition.

Another advantage possessed by this system is that the fuel enters the working cylinder in what is practically a gaseous mixture, and consequently is in a very favourable condition for rapid ignition and combustion.

Practically perfect combustion is secured at all times after starting the engine, by spraying the oil into the heated pump, as only dry gas is passed into the working cylinder, and there are therefore no particles of spray to condense in the working cylinder, and by partial oxidation cause imperfect combustion.

When once the motor has become heated up, the combustion continues to be perfect, and the exhaust remains invisible and odourless even at loads and speeds varying within a wide range.

In addition to the immunity from failure owing to impoverishment of the explosive mixture, which under the conditions described remains constant and inflammable, an additional safeguard against failure is provided by the fuel vapour pump, which is so designed that even at the lowest speeds the oil fuel will be subjected to a powerful atomizing action, whereas in engines working with direct spraying into the working cylinder, on a reduction of speed due to any sudden augmentation of load, the spray-producing effect of the suction stroke is considerably reduced, and a less perfectly atomized and inferior explosive charge enters the cylinder.

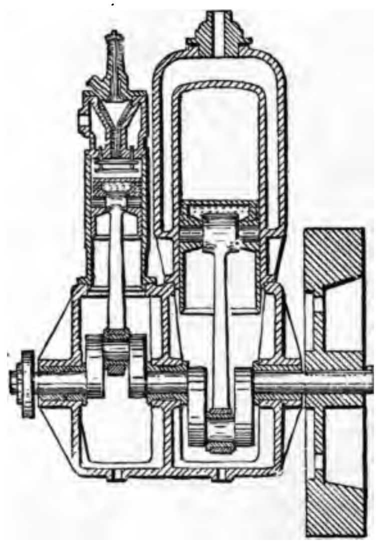

Fig. 116.—Allsop heavy-freight petroleum vehicles. Longitudinal section of engine.

The engine is admirably suited for the generator valve type of fuel feed used, that is to say, one in which the fuel passes through a small hole in the inlet valve seating, which feed cannot be applied economically direct to the working cylinder, as it is exceedingly difficult in that case to adjust the spring so as to properly throttle the valve and ensure effectual spraying of the oil fuel.

The governing of the engine can be effected as easily as that of an ordinary gas engine, and when the vapour supply is cut off, a charge of gas still remains in the pump, which charge is alternately expanded and compressed, so as to effectually prevent any condensation taking place, and this charge is vented into the working cylinder directly the gas valve again opens, no fresh charge of fuel being sprayed into the vapour pump until such

time as the gas valve is opened and the contained charge of gas passes to the working cylinder.

The result of the absence of all, or nearly all, condensation, which causes practically perfect combustion to take place, is an absolute immunity from all fouling or choking with sooty or tarry deposits from the oil fuel.

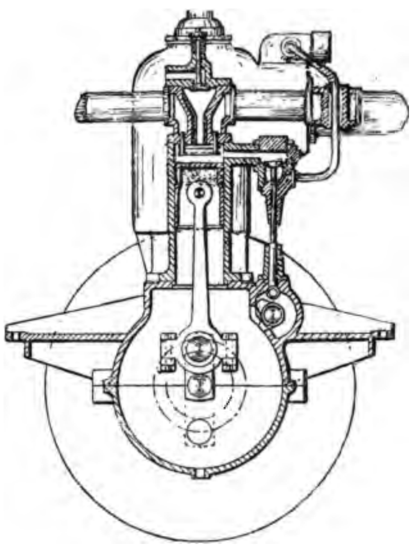

Fig. 117.—Allsop heavy-freight petroleum vehicles. Cross-section of pump.

The gas and exhaust valves are operated by hardened steel cams or wipers, mounted on a horizontal cam shaft and working against anti-friction rollers on the lower ends of the valve spindles, and driven from the motor crank shaft in the ordinary manner. The motor and cam shafts are enclosed in a dust-proof, oil-tight casing, and run in an oil bath with splash lubrication.

An arrangement is fitted which admits of the engine being started with "petrol," and run until the parts become sufficiently heated to allow of the heavy oil fuel being turned on. This device obviates the necessity of a preliminary heating of the parts by means of a blow lamp also provided.

Wolseley, Thornycroft, and other Heavy-freight Petroleum Vehicles

Heavy-freight petroleum or heavy oil engine vehicles are also built by the Thornycroft Company, Wolseley Company, and others. The latter vehicle is fitted with the same type of transmission gear as that so successfully employed on the well-known Wolseley touring cars, slightly modified, of course, in

order to render it more especially suitable for the purpose of the heavy-freight vehicles.

An excellent example of one of the latter type of vehicles is the 4-ton military transport waggon, which was shown at the Motor Car Exhibition held at Islington this year (1905).

This waggon is fitted with a 40-horse-power four-cylinder horizontal type of petroleum or heavy oil engine, having cylinders 6 ins. diameter by 7 ins. stroke respectively, and running at 600 revolutions per minute.

Amongst other heavy oil or petroleum engines in the market said to give good results, mention may be made of the following: The Kromhout (Dutch) heavy oil engine; that built by the Devon Engineering Company, Limited, The Harbour, Paignton; and the Vosper, Gardner, Hillier, Tolch, Roots, etc.

HEAVY-FREIGHT PETROL-ELECTRIC VEHICLES

Fischer Heavy-freight Petrol-electric Vehicles

These heavy-freight vehicles, the standard pattern of which is shown in Fig. 118, are built upon the same principle as the

Fig. 118.—Fischer heavy-freight petrol-electric vehicles. Standard lorry.

omnibus described on pp. 137–143, and that description, as also the diagram illustrating the running gear of the omnibus in question, apply equally well in the present case.

The Fischer Company build heavy-freight vehicles on this system with capacities of 5, 8, and 19 tons, the weights of the 5 and 8-ton vehicles, unloaded, being 3 and 4 tons respectively.

The maximum speed is 6 miles an hour, and any gradients usually encountered and surmounted by horse-drawn vehicles can be negotiated with ease.

The cost of running is given as $1\frac{1}{2}d.$ (2·5 cents) per mile on average roads.

Thury Heavy-freight Petrol-electric Vehicles

Self-propelled heavy-freight vehicles on this system (Thury's patents) are also constructed by the Compagnie de l'Industrie Electrique et Mécanique, of Geneva.

A feature in the dynamos made by this firm, and used in these vehicles, is the arrangement for compensating to a certain extent for a fall in voltage when at full load, by providing the shunt with a fine-wire winding placed in derivation, and with a compound winding of thick wire.

CHAPTER IX

HEAVY-FREIGHT VEHICLES (*Continued*)

Heavy-freight Electric Vehicles—General Observations—Examples of Heavy-freight Electric Vehicles.

HEAVY-FREIGHT ELECTRIC VEHICLES

General Observations

THE backwardness that has hitherto existed in this country in the use of electricity has naturally tended to retard the development of the electric-driven motor vehicle, and more especially has this been the case with respect to heavy-freight electric vehicles.

Electrically propelled vehicles present undoubted advantages for use on the comparatively smooth streets and roads that ought to be met with in and about large towns and cities, and consequently they are pretty extensively employed abroad, and especially in the United States; but here the general bad condition of the paved thoroughfares, and the deplorably bumpy macadam and soft, foundationless gravel roads which, in spite of the scandalously high rates, are the general rule, especially in and around London, has discouraged and kept back the use of electric motor vehicles, as it has, indeed, to a lesser extent, other self-propelled freight vehicles.

The electric equipment of a vehicle renders it both clean, inoffensive, and easy to handle. The suitable commutation of battery cells forming a feature of the electric system of propulsion, and which can be brought about through interconnection of contacts on the "controller," in conjunction with the series and multiple arrangement of the motor, gives considerable flexibility in the power and speed conditions of the driving mechanism, and the electric-driven vehicle may be said to be practically flexible and noiseless, as well as clean, inoffensive, and easy to

handle, devoid of heat and vibration, or practically so, and is, besides, the only power which checks automatically and naturally the consumption of energy even with light loads, almost in proportion to the power delivered. The electric motor will run equally well in either direction, and will work with an overload of several hundred per cent. for short periods.

For long distances, however, the use of storage batteries in heavy-freight vehicles is found in practice to be fraught with many disadvantages, so much so, indeed, as to become prohibitive, and on rough roads with heavy-freight vehicles—and more especially with those fitted with iron or steel tyres—the jarring and vibration imparts such severe punishment to the batteries as to render their use all but impracticable. This latter feature must obviously, therefore, greatly limit the use of electrically driven heavy-freight vehicles in this country until such time as the ratepayers insist upon a proper return for their money from the authorities in the direction of paving and road-making.

As regards cost, the best traction cell has a capacity of about 7 watts to each pound of its weight, and if this be taken as a basis to go upon, it will be easy to calculate what the dead weight will be that would be required for the propulsion of a heavy load for a long distance with one charge. In addition to the actual cost of charging, however, the maintenance of batteries forms a considerable item.

EXAMPLES OF HEAVY-FREIGHT ELECTRIC VEHICLES

Hudson Heavy-freight Electric Waggon

This waggon, which is shown in Fig. 119, with the body tipped for unloading, was built to the designs of the Hudson Coal Company, Jersey City, New York, and is especially intended for the delivery of coal; the carrying capacity of the waggon is 5 tons.

The main feature of this waggon is the arrangement for tipping, and the long sheet-iron chute which is adapted beneath the vehicle. The mechanism employed comprises a small but powerful electric windlass, driven by an independent electric motor, geared with large reduction through toothed gearing on

the right-hand side of the vehicle to a transverse shaft 2 ins. in diameter, and mounted centrally in the frame. Upon this shaft wind two chains, which slowly draw the forward end of an extended set of toggle levers towards the centre of the frame, and thus cause the middle portion of the levers to rise and force

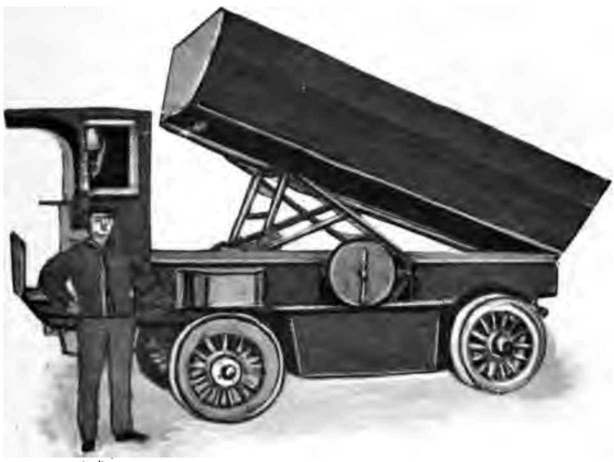

Fig. 119.—The Hudson heavy-freight electric waggon.

the body of the vehicle upwards, the front end rising to a height of 5 ft. and the rear end to a height of 2 ft. above the frame.

This vehicle is said to afford every satisfaction, being entirely successful from a commercial point of view. It makes from four to six trips daily, according to distance, from Jersey City to New York, with 5-ton loads, one man only being required in charge.

The Vehicle Equipment Company Heavy-freight Electric Vehicles

Several types of heavy-freight vehicles propelled by electric power are built by the Vehicle Equipment Company, who are represented in this country by the Anglo-American Motor Car Company, Limited, London.

Fig. 120 shows a 4-ton trolley built by this company, and

used for the transport of flour, which it is claimed to perform with complete success. They have also constructed a number of lorries, waggons, furniture vans, and other heavy-freight electric

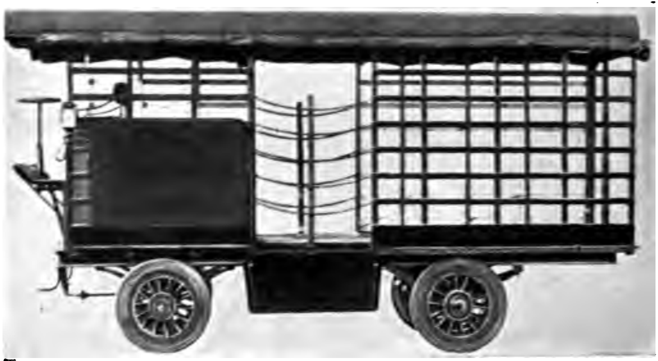

Fig. 120.—The Vehicle Equipment Company heavy-freight electric trolley.

vehicles, the frames and running gears of all of which are designed upon the same principle as those of their electric omnibuses, which have been already described and illustrated on pp. 145 to 147, and which consequently need not be again gone into.

CHAPTER X

SELF-PROPELLED VEHICLES FOR MUNICIPAL PURPOSES

Dust and Refuse Collection Waggons—Street Watering and Washing Machines—Street Sweeping Machines—Removal of Snow, etc.

An important field for the use of self-propelled or motor vehicles has been found in the various works now commonly undertaken with more or less success by municipal authorities in this country, such as the collection and cartage of refuse, water sprinkling and street washing, street sweeping, sprinkling of sand and gravel, removal of snow, and, amongst many other obvious services, that of the cartage of road metal, paving stones, and such other materials as may be required from time to time in connection with municipal work.

Hitherto the municipal waggon has been almost exclusively steam-driven, but in all probability the advent of motor waggons, having some efficient types of heavy oil or petroleum engines as prime movers, will result in the latter entering the field as competitors with steam for municipal purposes. The present advantage of the latter power rests in the fact that the fuel used—coal, coke, or refuse oil—is cheaper than the petrol spirit employed in petrol waggons, not to mention the element of danger always present where the latter fuel is employed. The cost for fuel in case of a steam-driven waggon may be put at less than 1*d.* per mile for a gross load of 6 tons, a performance which is scarcely possible in the case of a petrol waggon when used on such duties as are demanded in municipal work, wherein frequent stoppages, reversing, etc., are of necessity required. A well-designed compound steam engine, with enclosed cranks and connecting rods, moreover, requires no other attention for months on end beyond the necessary supply of lubricating oil to the crank chamber. By means of the reversing lever the power can be varied through a

considerable range, which is capable of being increased when necessary by the admission of live steam into the low-pressure cylinder. There is also a greater uniformity of driving effort in the case of a double-acting steam engine in which each cylinder gives two driving impulses to each revolution, instead of one impulse to two revolutions, as in the case of the internal combustion engine. Finally, the transmission gear is simpler in the case of a steam engine, and reversing can be effected in a comparatively simple manner.

The advantage possessed by the internal combustion engine in the absence of a boiler, and the consequent reduction of the

Fig. 121.—Coulthard 5 to 6-ton municipal steam tip waggon.

tare weight of the vehicle, besides that stoppages to take up water are not required, do not count for so much in the case of municipal work, confined, as it is, to a comparatively restricted area. These and other advantages, however, now more prominent where the work is over long distances, will, when joined to cheap and safe petroleum fuel, place the internal combustion engine on practically equal terms with steam for municipal service.

As regards the removal of household refuse, the body of a vehicle intended for this work must obviously be constructed to tip, and preferably should consist of a separate part easily attachable or detachable from the under frame. It is also very desirable that the cart should be fitted with proper lifting or sliding metal covers. The tipping can be effected either by a screw or some other equivalent mechanical contrivance.

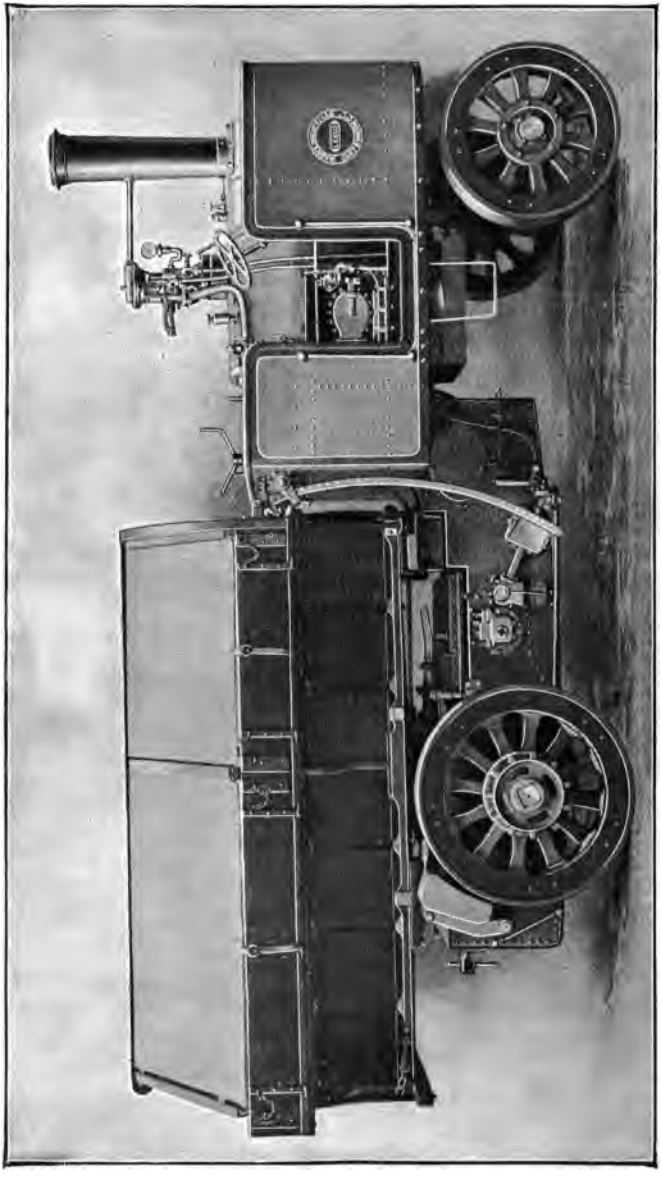

Fig. 122.—Mann covered municipal steam dust-waggon or cart with tipping body.

Motor dust-carts are made with capacities of from 6 to 10 cubic yards, against the $2\frac{1}{2}$ to 4 cubic yards of the horse carts.

Motor dust-carts or waggons are built by most of the makers of steam lorries or waggons, and several vehicles suitable for the purpose have been already illustrated, the general construction of the vehicles being, moreover, in all cases similar to that of the lorries or waggons with non-tipping or rigid bodies constructed by the same makers.

Fig. 121 is an illustration, giving a side view, of a 5 to 6-ton

Fig. 123.—Thornycroft standard municipal steam tip waggon, showing body tipped.

steam motor tip waggon built by Messrs. T. Coulthard & Company, Limited, Preston. Fig. 122 shows a covered steam motor tip waggon or dust-cart built by Messrs. Mann's Patent Steam Cart and Waggon Company, Limited, Leeds. Fig. 123 illustrates a steam motor tip waggon having a capacity of 7 cub. yds., built by the Thornycroft Steam Waggon Company, Limited, Chiswick, and Fig. 124 shows a steam motor waggon with a capacity of 9 cub. yds., constructed by the Lancashire Steam Motor Company, Limited, Leyland, all of which firms

have supplied quite a number of the above vehicles to municipal bodies. As already observed, the general arrangement of these waggons is similar to that of the steam lorries built by the same makers, which will be found described and illustrated in a previous chapter.

Messrs. James Robertson & Sons, of Fleetwood, whose standard 5-ton waggon has been described and illustrated on pp. 206 to 210, also make, amongst other patterns, a waggon fitted

Fig. 124.—The Lancashire standard municipal steam dust-waggon, with removable tipping body.

with an hydraulic tipping device, consisting of a ram into which water can be forced from the usual 150-gallon storage water-tank.

The question of cost of running and maintenance will be found dealt with generally in a subsequent chapter, but as regards the advisability or otherwise of employing steam waggons for dust collection, the following remarks made by Mr. A. Ventris, engineer to the Strand Board of Works, in a statement to the Liverpool Self-propelled Traffic Association, and by other authorities upon the subject, will be of interest. "I have every confidence," says Mr. Vestris, "in urging, not merely recommending,

the adoption of motors for use in operations similar to those so admirably carried out in the Strand district. The warnings I would give are: (*a*) concentrate sufficient dustmen upon the motor to permit of its large capacity being taken advantage of; (*b*) arrange for all repairs to be made promptly, and for periodic tightening of the wheels in an hydraulic tyre-setting machine; (*c*) work the motor two shifts per day."

According to Mr. Winter, of Hampstead, after having two steam dust-carts at work for nine months, it was found that a good deal of time and value was lost when the motor was about the street for collection purposes, and the result was that, compared to horse haulage, it did not work out economically, even with the use of a trailer worked in connection with the motor. It may be observed that the destructor plant for Hampstead is located some three miles outside the boundary of the district, which circumstance should be in favour of the use of motor dust-carts or waggons.

Three or four months' experience of the use of the above motors for street watering and haulage, on the other hand, resulted in a very distinct advantage, each motor being found to perform the work of four horses and carts. The horses and carts cost 9*s.* 8*d.* each, or £1 18*s.* 8*d.* for the four, whilst the motor (including driver's wages, allowance for depreciation and repairs) cost £1 8*s.*, thus showing a saving of 10*s.* per day, or about £155 a year. The Hampstead motor carts cost £700 each, including two bodies, one for the collection of dust and the other for street watering.

The saving effected by the use of motors for dust collection and street watering is estimated by Mr. Ventris at £173 12*s.* per motor; or if the water van be fitted with foot levers, so as to enable the services of an attendant at 25*s.* per week to work the levers on day shift to be dispensed with, the saving would be £238 per motor.

The collection of dust or house refuse is undoubtedly the most variable item to be found in municipal work, and the advantages to be gained by the use of motor dust-carts or waggons must of necessity differ considerably in accordance with existing local conditions.

Mr. T. W. E. Higgens, A.M.I.C.E., Chelsea, is of the opinion that for general cartage and street watering, and sweeping, motor

vehicles are preferable, but that for the collection of street dust and house-to-house refuse too much time is wasted in stoppages.

Mr. W. Weaver, M.I.C.E., Kensington, also recommends motors for street sweeping and watering.

Mr. A. Sharp, B.Sc., A.M.I.C.E., in a paper on "Municipal Motor Waggons," read before the Sanitary Institute Congress, at Manchester, says: "To secure the maximum economy in working motor tip waggons, the collection of refuse and the filling of the vehicle should be done as expeditiously as possible. The capacity of the motor tip waggon (7 cub. yds.) being two to three times that of a horse-drawn collecting cart, the number of labourers employed in filling should be greater. The speed of travelling being twice that of the horse-drawn cart, the time spent in travelling to and from the destructor, or tipping place, is halved. The same staff of fillers may keep a number of tip waggons going, one being filled while the others are on their way to or from the destructor. The average distance between the destructor and the points of collection will determine the number of motor waggons for a complete refuse disposal plant. In any case, as large a staff of labourers as is found convenient should be concentrated on filling one motor waggon, so that the time the motor remains practically idle is a minimum. One motor dust-cart has thus twice the speed and two and a half times the capacity of a horse cart."

"For street watering and sweeping purposes the motor waggon is undoubtedly specially qualified. The work in this case is of a regular and definite character, and the road surfaces to be run on should be at least moderately good. The substitution for the tipping body of a water tank of considerably more than double the capacity of a horse-drawn watering cart is only a matter occupying a few minutes' time. In the watering carts employed by Mr. Weaver, M.I.C.E., at Kensington, two water distributors are provided in conjunction with the water tank, viz. an ordinary sprinkler and a discharge valve for flooding or washing the roads before sweeping them. Obviously, motor watering carts can also be employed for the flushing of gutters and street drains with disinfectants."

For street sweeping either a horse-power rotary sweeper of the usual type may be hauled behind the motor, or a street cleansing machine propelled by steam power may be employed.

The first of these arrangements has been successfully used in Chelsea, the latter machine being in use in Kensington. An arrangement of the Thornycroft standard pattern of steam waggon, fitted with a water tank and a rotating brush, which latter can be replaced when desired by a spiral rubber squeegee, is illustrated in Fig. 125, and forms a very efficient machine. The requisite rotary motion is imparted to the brush from the driving axle of the motor through a set of toothed and chain gearing. This machine is said to have a capacity of 14,000 sq. yds. per hour, and to be capable of doing the work of eight ordinary horse-drawn rotating road-sweeping machines.

A motor road cleaner designed by Mr. F. Sadler for municipal

Fig. 125.—Thornycroft steam street watering and sweeping waggon.

purposes, which combines four distinct instruments, is shown in Fig. 126.

The main frame of this machine is constructed of channel steel of large cross section, and has also an underframe serving to stiffen the two axles, and carrying the main clutch of the motor and the change-speed gear, the arrangement of which does not differ essentially from that generally found on chain-driven cars.

The rear wheels are driven through chain gearing from sprocket wheels on the extremities of a transverse differential countershaft. The steering gear is of the usual type.

At the front of the main frame is mounted a large revolving brush, having its axis placed at a convenient angle to the direction

of travel, so as to enable the sweepings to be delivered to the side, as in the case of ordinary horse-drawn road-sweeping machines. A crane arm fixed to the frame takes the weight of the brush, and the latter can be raised or lowered by the driver through a hand wheel on a horizontal shaft operating a vertical screw through a nut and bevel gearing, as shown in the illustration. The brush is driven by chain gearing from a horizontal shaft on the main frame, which shaft is in turn driven by bevel gearing and chains from the rear wheels, the power being thus transmitted by one set of chains to the driving wheels, that required for revolving the brush being again transmitted back to another countershaft by another set of chains. Immediately in front of the brush are

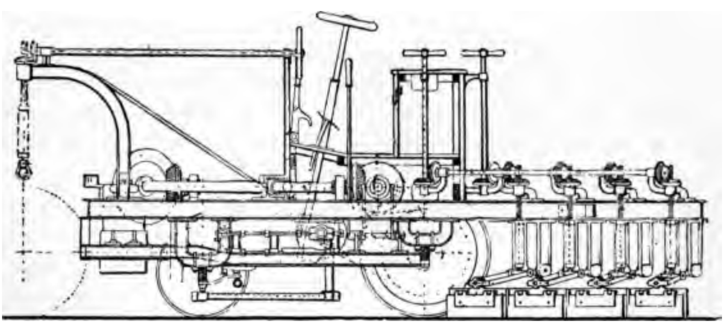

Fig. 126.—The Sadler municipal road-cleaning machine.

provided narrow rakes to break up the hard mud and enable it to be dealt with by the revolving brush.

Four overlapping squeegees placed at an angle to the frame are provided at the rear, and are so arranged that any or all of them can be brought into contact with the road surface by gear worked from the driver's seat. A similar number of scrapers are mounted behind the squeegees.

The numerous other uses for which motor vehicles can be advantageously employed in municipal work are obvious, and cannot be enlarged upon in the brief notice which the space at disposal permits of, but a few words must be said respecting the peculiar adaptability of the motor vehicle for the removal of snow.

A motor vehicle having non-slipping devices attached to the driving wheels, or fitted with a suitable sanding arrangement in

connection with the latter, and a snow-plough fixed in front, would be capable of dealing easily with a fall of snow several inches in depth. For lighter falls a trailing scraper would probably be the most convenient. Where motor vehicles are in extensive use, therefore, the provision of the above comparatively inexpensive snow removal attachments would provide a satisfactory solution of the problem of clearing snow from the roadway, and enable municipal authorities to deal with comparative facility with falls of snow, the difficulty of providing for the removal of which has hitherto been found practically unsurmountable.

In concluding this short chapter on municipal motor vehicles, the writer would point out that the satisfactory results which have been obtained when employing both horse-drawn and motor vehicles would be much enhanced were the former completely superseded by the latter. In this case the size of the plant would warrant the employment of a thoroughly competent foreman mechanic and sufficient skilled assistants to carry out all small repairs, periodical examinations, and replacing of worn parts, etc., and thus to admit of the vehicles being maintained in the highest practicable condition of efficiency, and consequently worked to the best possible advantage.

CHAPTER XI

MISCELLANEOUS TYPES OF MOTOR VEHICLES

Commercial Travellers' Motor Vehicles — Furniture Removal Motor Vans—Hospital Motor Ambulances—Motor Fire Engines —Self-propelled or Motor Railway Carriages—Overhead Conductor Electric Omnibuses—Motor Vehicles for Various Purposes —The Pedrail.

COMMERCIAL TRAVELLERS' MOTOR VEHICLES

A USEFUL type of self-propelled vehicle for business purposes is a motor brougham for the use of commercial travellers. The best power for a vehicle of this description seems to be the internal combustion engine, and as an excellent example of one of these machines may be taken that built by the Putney Motor Company, Putney, London. This vehicle is designed to stand hard work and to carry a load of 10 cwts. of samples. The driver is completely protected from the weather, and there is normally accommodation for two passengers, whilst by removing the upper part of the car four more can be seated. The interior is fitted up with a writing desk and electric light. Power is generated by a 16-horse-power petrol motor of the Craig-Dörwald type, which is capable of developing 24-horse-power on the brake.

Another pattern of commercial vehicle is that built by Messrs. Benz and Company, of Mannheim, Germany (sole agents for whom in this country are Messrs. Hewetson, Limited, London), which car is fitted up for the use of commercial travellers, and is driven by a 3-horse-power petrol engine.

The dimensions of this car are 7 ft. 6 ins. in length, 4 ft. 6 ins. in width, and 7 ft. in height. It is, as above mentioned, specially

arranged to suit the convenience of commercial travellers, and is provided with a hood, giving effectual shelter in the worst of weather. The compartment or case at the rear is fitted up with shelves to receive samples, from 4 to 5 cwts. of which can be carried, and it has secure lock-up doors. The weight of the vehicle, unloaded, is about 7·5 cwts. The sample case can, when desired, be easily removed, thus leaving the vehicle fit for pleasure purposes.

A brief description of the Benz system will be found in a previous chapter.

FURNITURE REMOVAL MOTOR VANS

For long distances self-propelled furniture vans should possess undoubted advantages, but for short journeys horse traction must, for the present at least, hold its own. A useful type of motor

Fig. 127.—Thornycroft steam furniture van.

furniture van is that with a removable van body fitted with slings. This arrangement not only admits of the van body being removed for transport by rail or on shipboard, but it leaves the lorry platform free, and the vehicle disposable for other purposes.

Fig. 127 shows a combination steam lorry and furniture van

of the above-mentioned description, which is fitted with extra strong frame and springs, and is capable of carrying a load of 4 tons. This vehicle is built by the Thornycroft Steam Waggon Company, Limited, and the construction of the running mechanism is practically the same as that of the standard steam waggon made by the company.

A steam furniture van similar to that shown in the illustration has been in constant use by Messrs. W. Whiteley, Limited, and obtained a first prize at the May Day Motor Van and Waggon Parade, in 1903.

An example of an electrically driven furniture van is shown in Fig. 128. This vehicle is built by the Vehicle Equipment

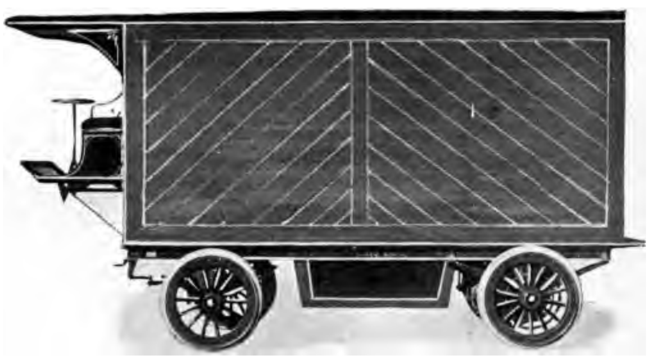

Fig. 128.—The Vehicle Equipment Company electric furniture van.

Company of New York (the sole agents for whom in this country are the Anglo-American Motor Car Company, Limited), the running gear being similar to that described in a previous chapter with reference to the delivery vans by the same makers.

HOSPITAL MOTOR AMBULANCES

For motor ambulances electricity would appear to be an ideal power. Absence of danger, smell, a minimum of vibration, and ease of control are essential features for this service. An electrically propelled vehicle is besides, so long as care is taken to keep the storage battery charged, available at any time for instant use, and the absence of any delay in starting is obviously

a most important consideration in the case of an ambulance. Steam is, however, also used, and in some ways possesses special advantages. The vibration of internal combustion engines renders them unsuitable for the purpose.

The above facts have been long recognized in the United States, and electric ambulances are in extensive use by all the best hospitals in that country. Fig. 129 is an example of an electric ambulance built by the Vehicle Equipment Company. As will be seen from the illustration, the vehicle is of the rear opening type. The bed is self-supporting when pulled out, and

Fig. 129.—The Vehicle Equipment Company electric ambulance.

its dimensions are 7 ft. 6 ins. in length by 3 ft. 4 ins. in width. The overall length of the vehicle is 11 ft., and the width of the body 3 ft. 9 ins. The interior is lined with white enamel veneering, and trimmed in either rubber cloth or leather, and a surgeon's seat, medicine cabinet, and all the other necessary appurtenances are provided, as well as a head light, side lights, and inside lights.

The ambulance has a maximum speed of 16 miles an hour, and a radius on one charge of 30 miles.

Another pattern of electric ambulance, having a side opening, and a lighting and ventilating lantern in the roof, is also built by the same makers.

Fig. 130 is a photographic reproduction of a Thornycroft steam ambulance which has been supplied to the Metropolitan Asylums Board, and run by them for some time with complete

Fig. 130.—Thornycroft steam ambulance.

success. The running gear is practically of the same pattern as that already described with reference to the heavy-freight vehicles and omnibuses made by the same firm.

MOTOR FIRE ENGINES

The application of the motive power of a steam fire engine to the propulsion of the machine along the roads to and from the scene of operation is an obvious one. It is not surprising, therefore, that a motor fire engine should have been one of the first motor vehicles to appear on the passing of the Motor Car Act.

In 1899 a self-propelled steam fire engine was built for abroad, by Messrs. Merryweather and Sons, Limited, Greenwich, the well-known fire engineers, who would doubtless long before have brought out a practical machine had an encouragement been forthcoming from the authorities in this country.

This machine differs but little from the firm's ordinary type of steam fire engine. The propelling mechanism is especially designed so as to be as simple as possible and to occupy the minimum of space, consistent with proper regard to strength, and free access to the various parts. The engine, when fully manned and carrying the necessary supplies of fuel and water, weighs under 3 tons. The boiler, in which steam can be raised in about six minutes from the time of lighting the fire, is of the pattern used in the engines supplied to the London Fire Brigade, the pumps being capable of delivering 300 gallons of water per minute, and throwing a jet to a height of about 150 ft. The steering wheel, throttle valve lever, reversing gear lever, and foot-brake lever are all located within convenient reach of the driver on the off side of the front seat, and an auxiliary screw brake can be operated from the footplate at the rear.

Tests of this machine before being despatched abroad proved that it was able to surmount with ease gradients of 1 in 10 at a speed of 10 miles an hour, whilst on ordinary roads from 15 to 20 miles an hour could be easily maintained.

Messrs. Merryweather have constructed several patterns of steam fire engines adapted to be either propelled by their own power or drawn by horses, as may be desired, the machines being practically replicas of their ordinary horse-drawn patterns adapted to travel by steam power.

The propelling machinery of this type of machine consists essentially of a countershaft supported in gun-metal swivel bearings secured to the frame. This countershaft is driven by toothed-wheel gearing from the crank shaft of the engine, and on its outer extremities are fixed bronze chain wheels, which latter are geared to the driving sprocket wheels secured to the spokes of the driving wheels, through chains of the roller pattern, with suitable provision for taking up wear. Balance gear provided on the countershaft enables the engine to negotiate sharp corners with safety. The main frame of these machines consists of two parallel bars of channel steel firmly fixed together by means of angle-steel box stretchers.

In Fig. 131 is illustrated a more recent type of self-propelled steam fire engine built by the above-mentioned firm, one of which machines, supplied to the fire brigade of Leyland, Lancashire, is the first motor fire engine to be placed in service in this country,

many other motor fire engines having, however, been previously shipped abroad.

The motor fire engine under consideration has a quick-steaming boiler, of the water-tube type, petroleum or liquid fuel being employed, reservoirs for which are placed beneath the hose box. The engine is a double-cylinder one, and is coupled to the driving wheels through sprocket and chain gearing and a countershaft with a clutch, which admits of the power of the engine being disconnected therefrom when required. By means of a coupling

Fig. 131.—The Merryweather steam motor fire engine.

device of very simple construction, the water pumps, which are of gun-metal with a capacity of 300 gallons per minute, can be connected up with the engine when the machine has arrived at the scene of operation.

The steering is on the Ackermann principle, starting, stopping, and reversing levers, and the pedal lever of foot brake being within convenient reach of the driver on the front seat, and the hand wheel of a powerful screw brake admits of the latter being worked by the man on the footplate at the rear. The feed-water tanks for the boiler are placed at each side of the latter, and

sufficient water and fuel is carried for a run of several hours' duration.

At a test of this self-propelled steam fire engine, steam was raised in the boiler to working pressure in two minutes, and the motor started on the trial run.

Electrically propelled chemical fire engines or waggons fitted with hook ladders are used by the Vienna Fire Brigade, who have three of these chemical engines at headquarters and one at each sub-station.

The above brigade have also a number of steam-propelled fire engines, three at headquarters, one in each of the district fire stations and four steam-engine stations. These steam fire engines are of the three-cylinder type built by Messrs. William Knaust and Company, engineers, Vienna.

SELF-PROPELLED OR MOTOR RAILWAY CARRIAGES

The great increase in competition during recent years, and the demand of the public for more frequent train services, at reduced fares, has led railway companies, both in this country and abroad, to consider whether the loss necessarily entailed by the running of long and heavy trains, frequently only scantily occupied by passengers, might not be avoided by the use of self-propelled or motor railway coaches or carriages, and a much-desired economy be effected in this manner.

The steam motor railway carriage shown in Fig. 132 shows the most recent and standard type built at their Nine Elms Works, and now in use on the London and South Western Railway. The illustration is a direct reproduction from a photograph, for which the author is indebted to the courtesy of Mr. Dugald Drummond, M.I.C.E., the locomotive superintendent of the line.

The body of the carriage is supported, as shown in the illustration, upon a frame formed of channel section, and is mounted on two four-wheel bogies.

The engine and boiler are enclosed, as shown, and the cab is located at the extreme forward end. The design throughout is such as to secure the greatest possible amount of compactness consistent with efficiency. The cylinders are set on an incline, the connecting rods driving direct on to crank pins provided on

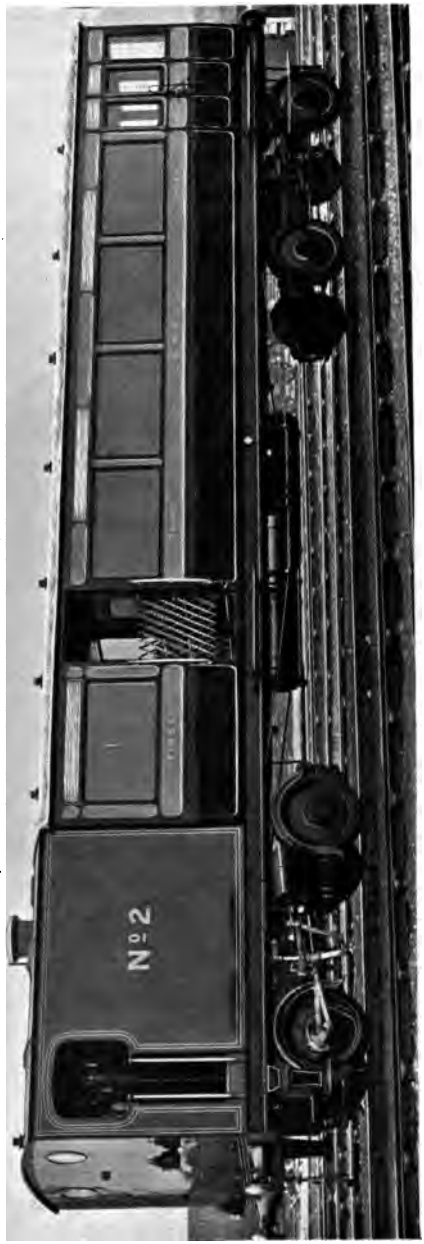

Fig. 132.—Steam motor carriage. London and South Western Railway.

the front wheels. The boiler is of the vertical type. The construction of the running mechanism is such as to admit of speed being very rapidly attained; the degree of acceleration is at the rate of about a mile per second, and will consequently give the carriage a speed of about 30 miles an hour in half a minute from starting.

Adjoining the engine is a compartment for 8 first-class passengers, access to which can be had from a platform protected by folding or collapsible gates of the Bostwick type. The third-class passenger compartment, which is adapted to accommodate 32 passengers, is approached from the same platform. At the rear of the carriage is a compartment capable of containing about a ton of luggage. Levers are provided in this rear compartment which enable the steam valves and brakes to be operated through suitable connecting rods, and the carriage to be started or stopped from either end, thus avoiding the necessity for turning at terminal stations. Electric communication is also fitted up between the cab and the body of the carriage.

A former type of motor railway carriage placed in use on the same line two or three years back had an overall length of 56 ft., and a passenger compartment divided into two sections by means of a sliding door, comprising a first-class compartment adapted to accommodate 12 passengers with the seats arranged longitudinally, and a third-class compartment capable of seating 30 persons with the seats placed in pairs transversely on each side of a central gangway.

The boiler in this type of carriage is arranged at the extreme forward end, a cab of the usual pattern being provided, next to which is a compartment capable of containing about a ton of luggage, separated by a platform protected by collapsible or folding gates of the Bostwick type from the passenger compartments.

Another platform similarly protected, and resembling that for brakemen on electric cars, is provided at the rear, and arrangement is made for enabling the carriage to be worked from this platform.

The weight of the complete motor carriage is stated to be somewhat less than that of one of the ordinary bogie carriages in use on the London and South Western Railway.

These motor railway carriages are capable of being worked by

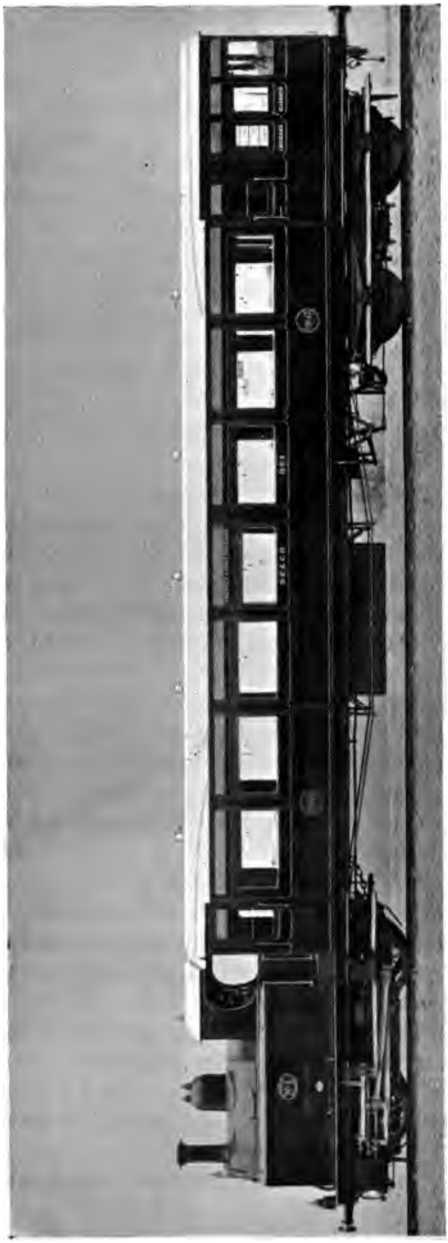

Fig. 133.—Steam motor carriage. South Eastern and Chatham Railway.

two men, a driver and a conductor, and the cost of working is said to be about 2·5*d.* per mile, including wages, etc.

Fig. 133 shows a steam motor railway carriage built by Messrs. Kitson and Company, Leeds, and the Metropolitan Amalgamated Railway Carriage and Waggon Company, Limited, Oldbury, for the South Eastern and Chatham Railway, to the designs of Mr. Harry S. Wainwright, M.I.C.E., chief mechanical engineer to the line, to whose kindness the author is indebted for the photograph from which the illustration is reproduced, and for the following particulars respecting the vehicle.

The engine is carried on a four-wheel bogie, the bogie centre pivot being fixed to a cross beam at the end of the carriage underframe, and the wheel base of the engine bogie being 8 ft., with coupled wheels 3 ft. 7 ins. diameter. The cylinders are placed outside the frames, and are 10 ins. diameter by 15 ins. stroke. The valve gear is of the Walschäerts type.

The boiler is of the locomotive type, and is fitted with a Belpaire firebox. It has the following heating surface: firebox, 44·5 sq. ft.; tubes, 337 sq. ft.; total, 381·5 sq. ft. The grate area is 8·8 sq. ft. The working pressure is 160 lbs. per square inch. Water tanks are placed at the sides and between the bogie frames, having a total capacity of 400 gallons. The coal bunkers are at the ends of the side tanks, and are capable of carrying about 15 cwt.

The engine can, if desired, be readily detached from the carriage, and can be run separate, when in steam.

The total length of the steam motor carriage over buffers is 64 ft. 11¼ ins., and the centres of bogies 42 ft.

The total weight of the steam motor carriage, when unloaded, is about 38 tons, which is distributed as follows: 24½ tons on engine bogie, and 13½ tons on carriage bogie.

This steam motor carriage is capable of taking, when required, an additional trailer carriage, weighing 16 tons, at a speed of over 35 miles per hour on a level, and at an average speed, including gradients, of 30 miles per hour.

The car runs very smoothly, indiarubber being largely employed to prevent vibration. The engine coal consumption is extremely small, and, as economy in maintenance has been especially studied in the design, a considerable saving in several directions will no doubt result.

The carriage body is 48 ft. 4 ins. long outside, and is divided

into three compartments, viz. a third-class non-smoking, next to engine, 19 ft. $10\frac{3}{8}$ ins. long; a third-class smoking, 14 ft. $10\frac{7}{8}$ ins. long; and a luggage and guard's compartment at the end, 6 ft. 8 ins. long.

There is a vestibule at the end, next to the engine, and also at that next the luggage compartment. Ordinary hinged doors, opening inwards, are placed on the side of the body, and sliding doors are arranged in the passenger and guard's compartments.

The passenger compartments are finished in teak, and the seats are arranged back to back, with a gangway down the centre. Ventilation is provided over each window and in the roof. Entrance to the car is effected by the end vestibule, leading to the non-smoking and the smoking compartments respectively. The seating accommodation is as follows: thirty-two non-smoking and twenty-four smoking. Electric lighting on Stone's system is fitted.

The underframe of the car is constructed of steel, and is carried at one end by a four-wheel carriage bogie, 8-ft. wheel base, with 3 ft. 6 in. wheels. The other end of the car, which is supported on the engine bogie, is cushioned with indiarubber pads.

A vacuum automatic brake is provided, and, in addition, a hand brake on the carriage and engine. The steam regulator, reversing gear, whistle, vacuum, and hand brakes can be worked by the driver from either end, and the guard can communicate with the driver by means of electric bells.

This steam motor carriage is now running on the Sheppey Light Railway.

A steam railway carriage, designed for the Barry Railway Company by Mr. J. H. Hosgood, M.I.C.E., the locomotive superintendent to the line, has been built by the North British Locomotive Company, Limited, and accommodates 51 passengers, viz. 10 in the first-class compartment and 41 in the third-class compartment.

The underframe carrying the body is constructed of steel channels 9 ins. by $3\frac{1}{2}$ ins., with angle-iron stretchers 8 ins. by $3\frac{1}{2}$ ins., with headstocks of the same size. The sole bars are stiffened with truss rods and formed in one length. The boiler seating consists of two stretchers of channel section 9 ins. by $3\frac{1}{2}$ ins., shaped to suit the boiler, and strengthened by 8 ins. by $3\frac{1}{2}$ ins. by $\frac{1}{2}$ in. angles riveted to the frame stretchers.

Over the headstocks the frame is 60 ft. 10 ins., and over the buffers 64 ft. 10 ins., the extreme width being 8 ft. 6 ins. A water tank capable of holding 500 gallons and a coal bunker with a capacity of 15 cwts. are provided.

The first-class compartment has the seats arranged longitudinally of the car, and is 8 ft. 3 ins. long; and the third-class compartment has the seats placed in pairs transversely of the car at each side of a central gangway, and is 25 ft. $10\frac{1}{2}$ ins. in length. The latter compartment is further divided into two sections, a smoking and a non-smoking. There is a gangway between the first and third-class sections protected by folding or collapsible gates. The luggage compartment, which is situated between the engine and the third-class compartment, is 5 ft. in length by 7 ft. $8\frac{1}{2}$ ins. in height at centre.

The engines are horizontal, with cylinders 12 ins. diameter by a stroke of 16 ins., fitted with Smith's patent piston valves and Walschäert's valve gear. They are arranged to drive direct on to the driving wheel, which is 3 ft. $7\frac{1}{2}$ ins. in diameter on the tread. From the centre of the cylinders to the centre of the driving axle is 11 ft., and from the centre of one cylinder to that of the other is 6 ft. 7 ins.

The boiler is 9 ft. 2 ins. high by an outside diameter of 6 ft. $0\frac{1}{8}$ ins., and 4 ft. 6 ins. diameter at the seating resting on the frame. It has 462 tubes of $1\frac{1}{8}$ in. diameter, with 133 copper stays 1 in. diameter. The heating surface is as follows: firebox, 45·41 sq. ft.; tubes, 550·00 sq. ft.; making a total of 595·41 sq. ft. The normal working pressure is 160 lbs. per square inch.

All the compartments, as also the tail and head lamps, are lighted by electricity on Stone's system, and an electric communication is provided between the guard and the driver.

An arrangement is also provided which admits of the valves, etc., being worked from either end of the carriage.

Another example of what has been done in this direction is a steam motor railway carriage which has been recently built from the designs of Mr. Manson, locomotive and carriage superintendent, at the Kilmarnock works of the Glasgow and South Western Railway.

The car is 60 ft. 8 ins. over the buffers, and is divided into three sections for passengers, having the guard's compartment at the rear, and the locomotive in front, with a cab of the usual type.

Each of the passenger compartments has a separate entrance door, and they are separated from one another by sliding doors. The seating accommodation is for 50 persons, and a central gangway admits of free passage from end to end of the carriage. The lighting is by Pintsch's oil gas.

The underframe of the carriage is of steel, and is carried on two suspension link bogies, that at the rear being of the ordinary standard type, whilst the front bogie is practically a small outside cylinder locomotive which is complete in itself, and so connected to the carriage that it can be easily detached. The cylinders are 9 ins. diameter by 15 ins. stroke. They are fixed horizontally on the bogie frame, and drive on to the trailing wheels, which latter are coupled to the leading wheels. The slide valves are placed on the top of the cylinders, and are operated by rocking shafts, link motion, and eccentrics of the standard pattern used on other locomotives on the line.

The boiler is of the locomotive type, with a copper firebox and 138 brass tubes $1\frac{3}{8}$ in. external diameter. It has a firegrate area of 8 sq. ft.; the heating surface of the firebox is 40 sq. ft., and that of the tubes 400 sq. ft.

Hand and vacuum brakes that can be operated from each end of the vehicle are provided, as also electrical communication between the guard and driver, and an arrangement whereby the former can sound the steam whistle from his van.

The dimensions of the carriage are as follows: length over buffers, 60 ft. 8 ins.; length over headstocks, 57 ft. 2 ins.; length of body, 41 ft.; from centre to centre of bogies, 39 ft. 4 ins.; bogie wheel base, 8 ft.; wheel diameter, 3 ft. 6 ins.

There is a water tank located beneath the car, having a capacity for 500 gallons, and coal bunkers are provided capable of containing 15 cwts. of fuel.

Hinged steps at the guard's compartment, worked by a lever, allow passengers to enter from the road level.

Efforts have also been made to adapt the internal combustion engine to the propulsion of motor railway carriages, in the United States, on the Continent, and also to a very limited extent in this country.

In the United States experiments have been made with more or less success in the direction of the propulsion of motor railway carriages by means of electricity generated on the car. For this

purpose a dynamo is coupled direct to an internal combustion engine, the electricity thus generated being conveyed to electric motors coupled direct to the driving wheels. This plan is, it will be seen, an adaption of the petro-electric system which has been described with reference to omnibuses and lorries.

OVERHEAD CONDUCTOR ELECTRIC OMNIBUSES

A system that has met with considerable favour abroad, and has secured some attention in this country, is one in which omnibuses, arranged to be driven by means of electric motors, derive the necessary supply of electric current from overhead conductors. The plan offers several important advantages, and affords an excellent means for working a service of omnibuses on a fixed route where, owing to the narrowness of the roadways, congestion of the traffic, or both these causes, the use of tramways is undesirable.

The chief advantages possessed by a system of electric omnibuses worked on the trolley system are, absence of rails on the road, which are a constant source of danger and annoyance; ability of the omnibuses to steer over any part of the roadway, instead of practically monopolizing it, as is the case with tramways; facility of installation and of removal from one route to another at a comparatively trifling expense; and lastly, an important feature in many cases, cheapness of first cost of the installation.

Experiments in this system of locomotion were first made in 1882 by Messrs. Siemens and Halske, of Berlin. The first practically successful installation, however, was that constructed by Mr. Max Schiemann, of Dresden, in conjunction with Messrs. Siemens and Halske, running from Koenigstein, Saxon Switzerland, along the Biel valley. The system was also exemplified both at the Turin Exhibition and the French Exhibition at Vincennes in 1900.

The omnibuses are made both semi and completely closed, both types being arranged for the accommodation of 26 passengers. The body of each vehicle is mounted on two single-wheel bogie trucks, the axles being supported in roller bearings, and the trucks being connected by cross pieces, so that the axles will move

equally. The wheels are of the artillery pattern, and all of the same diameter, no differential gearing being employed.

The body is connected to each truck by means of four vertical pivots, and the steering is effected by a like number of horizontal ones, an arrangement that leaves the central portion of the truck free for the brake lever, and allows of the brake being applied when running round curves without interfering with the movement of the bogie trucks.

An 8·5-horse-power electric motor, suspended at the centre of gravity, is connected to each of the rear wheels. The speed of the motors averages 900 revolutions per minute, and there is independent transmission to each wheel through single reduction (one-tenth) Grisson gear.

The driver's seat is placed in front on the frame of the omnibus, and is protected from the weather by a forward extension of the roof. The shaft or spindle of the steering gear passes through the hollow or tubular shaft of the speed regulator, and hand wheels upon these shafts are placed one above the other within convenient reach of the driver's seat. The weight on the front steering wheels is about one-third of the total weight, and the frame is supported upon six springs.

The shoes or skates forming connection with the overhead wires are forked, and have soft metal linings, and grooves to contain lubricating material are provided. The shoes are free to move both on horizontal and vertical axes, and springs ensure proper contact, the arrangement being such, moreover, that the shoes and the vehicle are always parallel to one another.

Two overhead wires, about 20 ins. apart, are provided, one of which is for the return current, and the shoes are carried upon rods of light cane or steel tubing, and the omnibus is permitted a play of 10 feet on each side of the wires, which latter are suspended from cross wires or hangers in the ordinary manner. A speed of 14 kiloms., or 8·698 miles, an hour can be attained.

An installation on the above principle, working in the environs of Paris, has a pair of trolley wires supported on short brackets on one side of the road, on which wires runs a two-wheeled trolley fitted with a small electric motor for its own propulsion, and connected with the omnibus by means of a flexible cable connected to a pole on the roof. Suitable devices are also provided for keeping this cable taut, and for preventing derailment of the trolley.

Through the trolley wheels and flexible cable a current at 500 volts is supplied to the motor of the omnibus, and the cable also contains three small conductors, which serve to convey back to the trolley motor the three-phase current by which it is driven. This current is derived from the main motor on the omnibus, which has three collecting rings on the armature at the end furthest from the commutator, and is connected to suitable points in the winding. This arrangement ensures synchronism between the speeds of the vehicle and trolley motor. In addition to this, an electro-magnetic brake is provided on the trolley motor, which can be energized through a sixth wire in the flexible cable.

The omnibuses each weigh about 3 tons empty and 5 tons fully loaded. The wheels are shod with solid indiarubber tyres. The power required for propulsion at ordinary speeds and on level roads is found to be from 130 to 160 watt-hours per ton-mile.

MOTOR VEHICLES ADAPTED FOR VARIOUS SPECIAL PURPOSES

As has been already mentioned, the heavy motor vehicles described in the foregoing pages can be fitted with bodies of various types adapted to suit different services without the general principles of construction being departed from in any material manner. A few of these heavy-freight vehicles for particular duties have been already briefly described and illustrated. The following are some of the numerous other uses to which such motor vehicles can be advantageously adapted.

For engineers' use for the transport of machinery, girders, etc.; for boiler makers, safe makers, and other manufacturers or transporters of heavy goods and plant. These vehicles can with advantage be provided with hoists for facilitating the handling of the loads. Vehicles with specially designed bodies are also made for the use of brewers, millers, pianoforte makers, farmers, market gardeners, builders and contractors, general carriers, dairies, bottlers, florists, advertising contractors, chocolate, cocoa, and sweet manufacturers, the transport of theatrical scenery and properties, the transport of canes on sugar estates, tank waggons for the conveyance of oil, and for many other special purposes too numerous to mention.

In agriculture, besides the obvious use of the motor in the form of various types of waggons for the transport of farm produce

it can be advantageously employed in the form of a tractor for the haulage of any description of three-furrow ploughs, scufflers, mowing machines, reapers and binders, and, in fact, any description of agricultural implement.

A motor specially adapted for this description of work is that made by the Ivel Agricultural Motors, Limited, of London and Biggleswade. This machine is capable not only of acting as a tractor, but also of driving all kinds of agricultural machinery. The motor is driven by a 14-horse-power petrol engine, and is supported upon three wide wheels, two at the rear, used for driving, and a single front one, which is used for steering.

The weight of this motor being only 28 cwts., it can be run on most roads, and makes scarcely any impression on the land.

In trials carried out with this tractor, hauling a three-furrowed plough, 6 acres 1 rood 9 poles of very hard-surfaced land was ploughed to an average depth of 7 ins. in 8 hours and 54 minutes, the cost working out at the rate of 5*s.* per acre, including everything. Drawing a reaping and mowing machine, 19 acres of wheat were cut in ten hours, at a cost of 1*s.* 9*d.* per acre, and 9 acres ofgrass were cut in 5 hours 13 minutes at a similar cost. Driving a chaff-cutter, 12½ cwts. of chaff were cut to a ⅜-in. gauge in 47 minutes at a cost of 2*s.* 6*d.*

THE PEDRAIL

This ingenious invention of Mr. B. J. Diplock, termed the Pedrail, has attracted considerable attention. It has been favourably reported upon by Professor H. S. Hele-Shaw and others, and has come successfully through severe trials.

The tractor belongs to the family of walking machines, and the invention consists essentially in substituting for the wheels of an ordinary traction engine revolving frames comprising sliding arms or spokes, each of which has at its extremity a circular foot, and at a short distance above the latter a roller. At the side of the machine in connection with each series of revolving arms or spokes is mounted a frame, of a shape somewhat resembling that of an inverted heart. On the revolution of the axle the spokes are carried round, placing the circular feet at their ends upon the ground in turn one after the other. Simultaneously, the rollers running round in contact with the heart-shaped

frame, on arriving beneath or on the broader portion thereof, act alternately to support the frame and to allow of its gliding over them. The machine is thus supported in turn through the rollers by the spokes which happen at the time to be resting with their feet upon the ground. The heart-shaped frame is so jointed and governed by springs that, on any of the feet meeting with an obstruction or inequality in the road surface, it will give to a sufficient extent to admit of its being surmounted.

In fact, the pedrail may be said to consist practically of two main parts; the one, a railway fixed to the axle box and non-revolving, the other, a species of circular box fitted with sliding spokes, rollers, and feet, so arranged that the feet are placed in succession on the ground and the rail runs over the rollers.

The feet are most ingeniously constructed, and possess not only great flexibility, but also have the arms or spokes so attached by sliding boxes, combined with ball and socket joints, as to be free to slide in every direction, a feature necessary to admit of the vehicle being turned. The pedrail is said to be capable of walking over 9-in. obstructions with ease.

CHAPTER XII

COST OF RUNNING AND MAINTENANCE

General Observations—Petrol Cabs—Petrol Omnibuses—Light Petrol Vans and Lorries—Heavy-freight Petrol Lorries—Heavy-freight Steam Lorries—Comparison of Cost of Running for Various Systems—Effect of Materials on Cost of Maintenance.

GENERAL OBSERVATIONS

THE actual working cost of a motor vehicle cannot be ascertained with the same accuracy as can be done in that of a stationary engine working with a practically constant load. In the latter case it is possible to get out the fuel consumption to several places of decimals, to work out *theta phi* diagrams, to estimate the actual brake horse-power per pound of fuel consumed, etc. In the case of motor vehicles this is rendered impossible, at least with any degree of mathematical accuracy, on account of the numerous factors entering into the question of their economical employment. It will be readily seen, indeed, that a few minutes delay in starting, varying conditions of the traffic, slip due to greasy roads, and many other contingencies, have important bearings upon the fuel consumption. In fact, in the case of a motor vehicle it is totally impossible to eliminate all personal elements as it is in that of a stationary engine.

As regards maintenance, this item must, in the case of motor vehicles, be unusually high, owing to the severe strains due to passing over uneven road surfaces, surmounting steep gradients, etc. Competent engineering supervision should be kept over the driver's work, and this is an item which must consequently be allowed for in estimates of cost. Heavy-freight vehicles should only be worked on five days a week, the sixth being devoted to a thorough overhauling, and some four or five weeks in each year will, in addition, have to be devoted to more extensive repairs.

The driver's and assistants' wages for the day devoted to the weekly overhauling (the washing out of the boiler in steam lorries, cleaning, overhauling, repairing, etc.) must be reckoned and added to the paying days. On the other hand, however, during the weeks devoted to extensive repairs neither the fuel nor the wages bill will run on. From this it will be seen that the annual working cost can only be estimated as spread over about 240 working days. Finally, it must be borne in mind that, in the case of heavy-freight vehicles, full loads must be carried in order to make them pay. Journeys with light loads or short journeys can only be profitably performed under very special circumstances, and where there is very little or no competition.

THE COST OF RUNNING AND MAINTENANCE OF PETROL CABS

At the present time it is not possible to give any actual positive data respecting the running and maintenance of petrol cabs founded on practical commercial working over a lengthy period, and estimates of cost made from purely theoretical deductions will doubtless be somewhat discounted in actual practice. Nevertheless, by making some allowances, such estimates may be taken as being sufficiently near the mark to enable useful comparison to be made as to cost relatively to horse-drawn vehicles.

The following figures are abstracted from a paper on the "Possible Development of Automobilism and Automobiles," read before the Scottish Automobile Club by Mr. William Weir, of Glasgow.

A $7\frac{1}{2}$-horse-power petrol motor cab, adapted to carry three persons, the driver, and luggage, could, according to Mr. Weir, be sold in lots of 50 for £350 each, which price would, he says, allow of a good honest job all through, pneumatic tyres, and a speed of 18 miles an hour. For depreciation £50 per annum is allowed, or 0·75*d.* per mile run, the vehicle having thus a life of seven years, and the distance run is estimated at 16,000 miles per annum, or nearly double that of an ordinary cab. For repairs, renewals, lubricating oil, and lamp oil, £45 per annum is allowed, or, including the cost of tyres, which latter item is based on French prices, nearly 0·685*d.* per mile. This estimate has been founded

by Mr. Weir on a careful analysis of touring car results, and is given by him as being a very ample allowance.

For horse-drawn cabs, the above authority allows two horses for each cab, the total daily average being 28 miles, which at 300 working days per annum gives 8400 miles. The capital account he estimates as—

	£
Two horses at £30 each	60
One cab	105
Harness	10
	£175

The life of the horses is put at seven years, that of the cab at fifteen years, and that of the harness at four years, the annual depreciation being £18 1*s.* 5*d.*, or 0·516*d.* per mile.

Food for two horses would cost £65 per annum, or 1·85*d.* per mile, whilst petrol for the motor should not exceed 0·375*d.* per mile. The wages of both horse and motor cab drivers are put down at 30*s.* a week, the first working out at 2·22*d.* per mile, and the latter at 1·17*d.* per mile. The rent of stables, rates, taxes, and stablemen's wages (not taking into account the management and office staff) is placed at £28 12*s.* per annum, or 0·81*d.* per mile for the horse cab, a figure which could be reduced two-thirds in the case of motor cabs, owing to the smaller space required. The cleaning, supervision, rent, rates and taxes, foreman, and all the other direct charges outside of management and office expenses, is estimated by Mr. Weir at £23 per annum, or about 0·345*d.* per mile for a motor cab, provided there be at least fifty cabs on the establishment. The non-requirement of the removal of horse manure is likewise a very considerable advantage on the side of the motor cab.

The above figures give as the total cost per mile run, without making any allowance for interest on capital in either case, for the horse cab 5·686*d.* and for the motor cab 3·325*d.*, and adding in both cases 5 per cent. interest on capital, we have respectively 5·936*d.* and 3·585*d.*, thus showing the estimate for the running expenses of the motor cab to be very considerably less per mile than that of the horse cab.

It must not be overlooked, however, that the advantage shown in the above estimate on the side of the motor cab is largely due to the greater distance that the latter vehicle is put

down as being capable of running in the year, and that in actual work the number of miles run is dependent on the ability to obtain fares, and not upon a capacity of running a given distance.

COST OF RUNNING AND MAINTENANCE OF PETROL OMNIBUSES

Petrol omnibuses have been, and are being now, run in many localities with profitable results, whilst in others, owing to severe competition, shortness of routes, and other local causes, they have not proved to be commercially successful.

In a lecture delivered by the Hon. C. S. Rolls at the London Institution early in 1904, mention was made of a number of services working successfully, and the following figures were given, showing the results obtained with one of the vehicles over a period of eleven days: Mileage covered, 820; passengers carried, 5312; receipts, £55 12*s.* 7*d.*; petrol consumed, 109 gallons; cost per mile for fuel and oil, 2·85*d.*; gross receipts per mile, 16·15*d.* This is claimed to leave for wages, depreciation, upkeep, and profit, 13·3*d.* per mile, whilst net takings of 11*d.* per mile are said to assure the financial success of such an undertaking.

The following figures were given in the report of the first year's working of the Eastbourne motor omnibus service: The number of passengers carried was 294,922, the total receipts from fares being £2069. The expenditure included the following items: Wages, £367; general repairs, £84; tyre repairs, £8; machinery repairs, £205; petrol, oil, waste, and cleaning materials, £365; worn-out tyres and depreciation on tyres still in use, £626. The total distance run was 36,800 miles, and the cost 13·6*d.* per car-mile; the cost of tyres was 4·09*d.* per car-mile; the cost per week of each car was £17 9*s.* This service has been a loss.

Mr. John Stirling states that the revenue on omnibuses, with a maximum capacity of fourteen passengers, run by the London Power Omnibus Company, is, according to their manager, 8*d.* per car-mile, whilst the working costs and expenses come out at 4*d.* per car-mile.

As a comparison with the above, the cost of running an up-to-date electrical tramway is put down roughly at 6*d.* per car-mile, whilst the revenue of the West London lines of the London United Tramways is about 11*d.* per car-mile.

THE COST OF RUNNING AND MAINTENANCE OF PETROL VANS

The cost of running and maintenance of light petrol vans is a matter regarding which practical information is still very scarce, and respecting which, in any case, it would be difficult to give any precise universally applicable data, inasmuch as it depends largely upon a variety of considerations relating to the manner in which they are used. It may, however, be safely calculated that under ordinary conditions of working the expense would be appreciably less than that of horse delivery vans.

The following particulars will give some idea of the probable cost of running light motor delivery vans.

At the Richmond trials in 1899 a Daimler motor (Post Office) van, and a light lorry of 1·5 ton capacity each, gave gross oil consumptions for the run of 50 miles of 24 pints and 22 pints, costing 3*s.* and 2*s.* 9*d.* respectively, the oil spirit being 6·68 sp. gr., and the price being taken at 1*s.* per gallon.

This makes the cost of oil spirit per mile for the van work out at 1·8*d.*, and per mile per ton at 0·45*d.*; for the light lorry the figures being 1·6*d.* and 0·75*d.*

The total weight of the van loaded is 3·95 tons. The engine has four cylinders, 3·56 ins. diameter each, by 4·75 ins. stroke, and makes 800 revolutions per minute. There are four changes of speed, the mean speed per hour being five miles. The total weight of the light lorry loaded is 2·14 tons. The engine has two cylinders 3·81 ins. diameter each, by 5·37 ins. stroke, and makes 660 revolutions per minute. There are four changes of speed, the mean speed per hour being 5·8 miles. The power of the latter engine is 6-horse-power nominal. Both the above motors have electric ignition.

The following estimate is given as applicable to a van on the Hagen system :—

	£	s.	d.
Cost of purchase (30 to 40 cwts.)	375	0	0
4 per cent. interest on £375	15	0	0
16 per cent. depreciation on £375	37	10	0
Cost of fuel on average of 30 miles per day, 1*s.* per 30 miles	15	0	0
Grease	2	10	0
Repairs per year	12	10	0
	£82	10	0

The daily work of 30 miles can be increased as much as desired.

The average speed of the petrol van being from 8 to 12 miles an hour, there would be an obvious saving of time for driver.

As compared with the above the cost of a two-horse van, four horses, two sets of harness, and necessary stable requisites is put down as £292 10*s*., and 4 per cent. interest on this sum, 20 per cent. for depreciation, plus cost of food, litter, shoeing, rent of stable, repairs, and veterinary expenses is estimated at £265.

THE COST OF RUNNING AND MAINTENANCE OF PETROL LORRIES

To ensure the commercial success of a petrol lorry service, as, indeed, also that of a steam lorry, it is absolutely essential that a sufficient mileage be covered, and in the case of a petrol lorry the minimum should be about 30 miles a day, or, say, 180 miles a week, with an average load of 3 tons. The minimum average rate should be 4½*d*. per ton-mile, including expense of collection and delivery.

Mr. Rolls places at about 24*s*. per week the working cost of a 4-ton lorry for a daily run of 40 miles for 5 days per week, with a short run on Saturdays, inclusive of interest, depreciation, fuel, repairs, wages, etc.

According to tabulated statistics compiled by a Birmingham firm of brewers, showing 6 months' and 28 months' working by horses and motors respectively, the cost of running the latter, including upkeep, wages, depreciation, insurance, etc., for 28 months (2 years and 4 months) was found to be £1086. The load carried during this period totalled to 2837 tons, and the distance covered was 5384 miles. The load carried by the lorry in 6 months was 819 tons, and the distance covered was 2734 miles. This firm consider the advantage of the motor lorry over a pair-horse dray to be about £200 per annum.

In an article on "Cartage Rates by Various Methods," published last August in the *Automobile Commercial Vehicle Review*, the writer says :—

"The initial outlay on a petrol lorry and trailer is more than for steamers, but the actual working cost per ton-mile is slightly better owing to a greater average mileage being more easily maintained with the same loads. There are no delays for getting up

steam or watering, and they generally travel faster under loads, as their tare weight is less, a great advantage on indifferent highways. Returning empty, a petrol waggon can run at the speed of a motor car. Assuming the cost of a petrol internal combustion lorry of the Cadogan type to carry 5 tons at £750, the annual expenditure will approximate as follows:—

	£	s.	d.
Driver, 35s. weekly	91	0	0
Man, 26s. ,, ...	67	12	0
Repairs	45	0	0
Oil (lubricating and fuel)	50	0	0
Insurance	15	0	0
Interest	37	10	0
Depreciation	112	10	0
Total	418	12	0

"Working 300 days per annum, the minimum amount to be earned daily will be £1 7*s.* 10*d.* As 50 miles with 1500 bricks can be run every day, the average cost per 1000 bricks per mile loaded both ways will be 4·45*d.* As in the case of the steamer on good roads, more weight can be carried over an increased mileage. For very long runs the petrol waggon is the most economical, as it can easily carry fuel for 200 miles. The advantages of a petrol waggon for up-country colonial work are comparable only with the oil fuel steamer, which, however, has its disadvantages when water for the boiler is scarce."

THE COST OF RUNNING AND MAINTENANCE OF STEAM LORRIES

Varying local conditions render it very difficult to give any definite cost for running expenses per ton-mile.

As a rule it may be assumed that with loads of 6 tons and over, and all from one place and to one place, steam lorries are cheaper than horses. For journeys of 20 miles and over, and with loads of 4 tons and over, the steam lorry is cheaper than the horse. For shorter journeys, however, of, say, 10 miles, the load must be between 5 and 6 tons.

Stopping to collect or to deliver portions of the load is fatal to economical working. It entails a deadened fire, cooled

cylinders, and unproductive consumption of fuel, with no counter-balancing advantage as a set-off.

The approximate annual expenditure on a 5-ton steam motor lorry or a 5-ton light locomotive with trailer costing £500 is given in the *Automobile Commercial Vehicle Review* as follows :—

	£ s. d.	£ s. d.
Wages—		
Driver at 35*s*.	91 0 0	
One man at 26*s*.	67 12 0	
		158 12 0
Repairs		44 7 6
Oil		16 12 6
Coal, 41½ tons		49 0 0
Insurance		11 18 0
Interest on cost		25 0 0
Depreciation		70 0 0
Incidentals		4 10 0
Total		380 0 0

Given 300 working days, the minimum amount to be earned daily will be 25*s*. 4*d*. As 40 miles with 1500 bricks can easily be performed, the average cost per 1000 bricks per mile works out at 5·6*d*. when loading both ways. The steam motor thus carries three horse loads, and is capable of travelling daily twice the distance, thus performing the work of six horses at a difference of 4½*d*. per 1000 bricks per mile cheaper. Where roads are exceptionally good, and there is plenty of help at each end of the journey, a greater weight can be carried, and more daily mileage covered. The motor will put in 144 hours weekly if required.

The following estimate for the annual expense of a steam waggon or lorry costing £650 is given by Mr. R. G. L. Markham, an engineer connected with the Thornycroft Steam Waggon Company, Limited, of Chiswick, in an article recently contributed to a monthly magazine :—

	£ s. d.
Interest on capital, 4 per cent.	26 0 0
Depreciation, 15 per cent.	97 10 0
Maintenance and repairs	60 0 0
Rent and rates	19 0 0
Oil and stores	10 0 0
Driver at 35*s*. per week	91 0 0
Lad at 20*s*. per week	52 0 0
	355 10 0

No allowance is made in this estimate for fuel or for insurance, whilst an item of £19 for rent and rates, not allowed for in the previous estimate, is included. If these matters be adjusted, and allowance be made for the greater cost of the second vehicle, the two estimates will be found to approximate very closely.

An analysis of the performance of a Thornycroft steam dray during 15 months' work is given by Messrs. Fuller and Company, brewers, Chiswick, as follows:—

Average total mileage per working day	33
Working days per annum	260
Net ton-miles per annum	25000

The total cost per net ton-mile, inclusive of interest, depreciation, wages, fuel, adjustments, repairs, and stores, is 3·4*d.* Taking the usual allowance of 5 barrels (each 36 gallons) per ton, it appears, therefore, that the cost of transport per barrel-mile is 0·68*d.* Messrs. Fuller and Company state that the vehicle easily does the work of three of their two-horse drays.

Messrs. Savage Brothers, Limited, give the following estimate of working cost of one of their 5-ton steam lorries costing £550:—

	£	*s.*	*d.*
Driver at 30*s.* per week	78	0	0
Fuel	40	0	0
Oil and waste at 5*s.* per week	13	0	0
Maintenance	50	0	0
Interest on cost (£550) at 5 per cent.	27	10	0
Depreciation at 15 per cent.	82	10	0
	291	0	0

In this estimate it will be seen that no allowance has been made by Messrs. Savage for a man to assist the driver, insurance, and incidentals. Adding, say, £85 for these items, the total would be raised to £376, or nearly that of the previous estimates.

A practical test of one of the Savage steam lorries transporting loads of from 4 to 5 tons for brewers and millers, and doing about 40 miles per day at an average rate of 5 miles an hour, is stated to have shown the cost of transport to be 2·25*d.* per ton-mile.

In an address delivered by Mr. E. Shrapnell Smith before the Liverpool Chamber of Commerce in 1901, the estimate given for the average annual working cost, for Lancashire, of motor waggons, according to roads and loads, is as follows:—

Class of work. 70 hours per week under steam. 5½ days. 50 weeks per annum.	Weight Capacity. Self-contained motor waggon, 4 tons.	Weight Capacity. Motor waggon and trailer, 7 tons.
	£	£
Prime cost	600	670
Interest at 5 per cent. per annum	30·0	33·75
Depreciation at 15 per cent. per annum ...	90·0	101·25
Fuel—coke at 15*s*. per ton	63·0	94·5
Wages—driver at 35*s*. per week	91·0	91·0
assistant at 17*s*. 6*d*. per week ...	—	45·5
Repairs and adjustments	75·0	90·0
Water, lubricants, and sundries	20·9	25·0
Insurances	12·9	15·0
Total per annum	381·0	496·0
Vehicle-miles per annum (280 days)—	Miles.	Miles.
A. On bumpy and badly paved roads; 30 miles per day	8,400	8,400
B. On average granite setts, etc.; 35 miles per day	9,800	9,800
C. On good macadam; 45 miles per day	12,600	12,600
Net ton-miles per annum—		
A. with full load	33,600	58,600
A. with ¾ load	25,200	44,100
A. with ½ load	16,800	29,400
B. with full load	39,200	68,600
B. with ¾ load	29,400	51,450
B. with ½ load	19,600	34,300
C. with full load	50,400	88,200
C. with ¾ load	37,800	66,150
C. with ½ load	25,200	44,100
Cost per net ton-mile—	*d*.	*d*.
A. with full load	2·7	2·0
A. with ¾ load	3·6	2·7
A. with ½ load	5·5	4·0
B. with full load	2·3	1·7
B. with ¾ load	3·1	2·3
B. with ½ load	4·7	3·5
C. with full load	1·8	1·3
C. with ¾ load	2·4	1·8
C. with ½ load	3·6	2·7

The performance of a Robertson steam lorry (the first vehicle of the type built by these makers), owned by the Fylde Motor

Carrying Company, gives a very good idea of what these vehicles are capable of doing in actual practical work under more than ordinarily trying conditions.

The waggon in question has been used for transport purposes between Fleetwood and Blackpool, a distance of about 12 miles, and a district where the roads are excessively soft, but little metal having been used in their construction. During the first season (1903) the distance covered exceeded 6000 miles, with loads of from 4 tons to 5 tons 5 cwts., and two journeys each way were frequently made. Owing to the unusually wet season, the condition of the roads was abnormally bad, but, notwithstanding this fact, it is stated that no trouble was experienced.

The lorry worked, moreover, under the disadvantage of having to pick up any available loads, and consequently the mileage varied daily, and, besides this, portions of the loads being consigned to parties at considerable distances apart, and in opposite directions, the delivery occupied a considerable time, and caused a very large increase in the fuel consumption. It may be also mentioned that on the return journeys the loads were almost always bricks, which necessitated the negotiation of the bad roads which are universally found about brickyards.

Upon the next page will be found a table giving the details of working of this lorry during 30 working days. The consumption of coke fuel varied from $4\frac{1}{2}$ to 6 cwts. per day.

The following is an estimate of the running charges of a Straker steam waggon; prime cost, £700 :—

Running charges.	£
Driver at 35*s*. per week ...	91
Labour, loading and unloading ...	35
Fuel ...	45
Water	5
Lubricating oil	11
Repairs	50
Standing charges.	
Depreciation at 15 per cent.	105
Interest on capital at 5 per cent. ...	35
Insurance at £15 per annum	15
Rent of shed at £20 per annum	20
	412

On the basis of 200 ton-miles per day, or 52,000 per annum, the running charges amount to somewhat less than 1·25*d.* per ton-mile, and the standing charges to 0·75*d.* per ton-mile. The total charge is thus 2*d.* per ton-mile.

ACTUAL WORKING OF ROBERTSON LORRY FOR 30 DAYS.

Date.	Runs between	Class of goods.	Ton-miles.	Light-miles.	Total loaded.	Total light.
1903						
July 23	Fleetwood and Blackpool	Corn	64	12		
24	,, ,,	Corn and bricks	148	5		
25	Sat. ,, ,,	,,	73½	5	285½	22
27	,, Blackpool and Lytham	,,	146¾	8		
28	,, and Blackpool	Bricks	84	24		
29	,, ,,	,,	105	19		
30	,, ,,	,,	63	12		
31	,, ,,	,,	126	24		
Aug. 1	Sat. ,, Cleveleys and Blackpool	,,	41	17	566	144
5	*Bank Holiday Week.* ,, and Blackpool	Corn and bricks	134½	12		
6	,, ,,	,,	132½	12		
7	,, ,,	,,	132½			
8	Sat. ,, ,,	,,	70½		470	24
10	,, ,,	,,	132½			
11	,, ,,	,,	132½			
12	,, ,,	,,	109½	12		
13	,, ,,	,,	109½	12		
14	,, ,,	,,	74½	12		
15	Sat. ,, ,,	,,	68¼	12	626	48
17	,, ,,	,,	117½	24		
18	,, ,,	,,	113			
19	,, ,,	,,	55	12		
20	,, ,,	,,	63	12		
22	Sat. ,, ,,	,,	141		489½	48
24	,, ,,	,,	63	12		
25	,, ,,	,,	123			
26	,, Singleton and Blackpool	,,	138	14		
27	,, and Blackpool	,,	44½	12		
28	,, ,,	,,	139½	5		
29	Sat. ,, ,,	,,	45	12	546	55

Total ton-miles 2983 ÷ 30 working days, 99·43 average per day.
,, light ,, 301 ÷ ,, ,, ,, 10·03 ,, ,,
,, waggon ,, 3284 ,, ,, ,, 109·46 ,, ,,

The Lancashire Steam Motor Company, Limited, give the following estimated annual expenditure, based on 300 working days; prime cost of waggon, £550 :—

	£	s.	d.
Depreciation at 15 per cent. on £550	82	10	0
Interest on capital outlay at 5 per cent.	27	10	0
Driver at 30*s*. per week	78	0	0
Loader at £1 per week	52	0	0
Coke at 12*s*. per ton	37	16	0
Water, lubricants, and sundries	20	0	0
Repairs and adjustments	50	0	0
	347	16	0

Calculations based on the above estimate on the basis of 22,644 net ton-miles only per annum, give the total charges as 3·6*d*. per ton-mile.

The following is an estimate of cost from an actual week's work of a Londonderry steam waggon :—

	£	s.	d.
Interest and depreciation at 20 per cent.	1	12	6
Driver, wages paid	1	16	0
Fireman, ,, ...	1	4	0
Fuel, 31 cwts. of coke at 8*d*.	1	0	8
3 gals. oil at 2*s*.	0	6	0
2 lbs. motor grease at 4*d*.	0	0	8
1 gal. paraffin at 7*d*.	0	0	7
2 lbs. waste at 2*d*.	0	0	4
Firewood	0	1	0
Third man assisting delivery	1	0	0
Set aside for repairs	0	15	0
	7	16	9

Taking 50 weeks, or 300 working days, to the year, this would make the annual expenditure £391 17*s*. And £7 16*s*. 9*d*. per week = £1 6*s*. 1½*d*. per day. £7 16*s*. 9*d*. ÷ 897 ton-miles during week = about 2*d*. per ton-mile.

The steepest gradient negotiated during the test was 1 in 7, and the time of the year was January, with the roads in bad condition.

Estimate by the makers of the approximate weekly working expenses of a Wantage steam lorry; prime cost, £500 :—

	£	s.	d.
Depreciation at 5 per cent.	0	9	7
Driver's wages	1	10	0
Repairs	0	10	0
Coke fuel at 3*s.* 6*d.* per day	0	17	6
Oil grease and waste	0	5	0
	3	12	1

In this estimate no allowance is made for interest, or stoker's or loader's wages, and the allowance for depreciation and repairs is considerably less than that in previous estimates. An adjustment of these points will be seen to bring the estimate to approximate pretty closely with those already given.

The following table is taken from an interesting paper read by Mr. Douglas Mackenzie at a meeting of the Society of Engineers in October, 1903:—

TABLE GIVING THE COST OF WORKING MOTOR LORRIES.

Tons per journey ...	Two	Three	Four	Five	Six	Seven	Eight	Nine	Ten
Capital cost of motor waggon ...	£500	£537	£575	£612	£650	£687	£725	£762	£800
Ton-miles per day ..	30	41	52	63	75	86	97	108	120
	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
Wages	0 7 6	0 8 5	0 9 4	0 10 3	0 11 3	0 12 2	0 13 1	0 14 0	0 15 0
Fuel	0 5 0	0 5 0	0 5 0	0 5 0	0 5 0	0 5 6	0 6 0	0 6 9	0 7 6
Stores, oil, etc. ...	0 1 6	0 1 6	0 1 6	0 1 6	0 1 6	0 1 8	0 1 10	0 2 0	0 2 3
Repairs and renewals	0 7 6	0 7 6	0 7 6	0 7 6	0 7 6	0 7 9	0 8 3	0 9 0	0 10 0
Supervision ...	0 5 0	0 5 0	0 5 0	0 5 0	0 5 0	0 5 0	0 5 0	0 5 0	0 5 0
Interest on capital ...	0 2 1	0 2 3	0 2 5	0 2 7	0 2 9	0 2 10	0 3 0	0 3 2	0 3 4
Depreciation ...	0 10 5	0 11 2	0 11 11	0 12 9	0 13 6	0 14 4	0 15 1	0 15 10	0 16 8
Insurance	0 2 1	0 2 1	0 2 1	0 2 1	0 2 1	0 2 1	0 2 1	0 2 1	0 2 1
Total	2 1 1	2 2 11	2 4 9	2 6 8	2 8 7	2 11 4	2 14 4	2 17 10	3 1 10
Cost of same work with horses ...	1 0 0	1 7 6	1 15 0	2 2 6	2 10 0	2 17 6	3 5 0	3 12 6	4 0 0

In the above table the cost has been worked out at per day on the assumption that the motor is in use for 240 days in the year, and the working day is taken at 10 hours. It is assumed that the return journey is made empty. It is also presumed that, the

weight of the usual load being known, a motor designed to carry that load will be used. If the load be under 5 tons it is best to carry it all on the motor. If, however, the load be 5 tons or over, it is best to distribute it between the motor and a trailer, and the cost of a trailer is therefore included with that of a waggon for loads of 5 tons and upwards.

As regards depreciation, the above authority considers that in the case of a motor lorry by one of the best makers, a fair allowance to write off is 25 per cent. the first year, and on each succeeding year 25 per cent. of the value as reduced by the deduction of the depreciation.

COMPARISON OF COST OF RUNNING FOR VARIOUS SYSTEMS

The following table will be of interest, as it shows at a glance the cost of running in pence per ton-mile for both light goods delivery vehicles and of heavy-freight vehicles driven respectively by petrol, steam, and electric motors, of stated horse-powers, load capacities, and maximum speeds per hour.

TABLE OF COMPARATIVE CHARGES OF VARIOUS FREIGHT MOTORS.

Light goods delivery vehicles.	Horse-power developed.	Load in cwts.	Maximum speed per hour, unloaded.	Charges in pence per ton-mile.
Petrol	6–10	10–20	12–20	1·5–1·75
Steam	4–8	8–13	12–20	1·75–3·75
Electric	3–6	16–22	12–15	1·75–2
Heavy-freight vehicles.				
Petrol	12–34	40–160	15–20	2·5–5
Steam	16–40	40–200	12–16	2–4
Electric	12–20	40–100	11–16	2·75–5

The apparent superiority of the light goods delivery vehicles is due to the faster speeds at which they run under light loads. The maximum speed under load is about half that running light.

EFFECT OF MATERIALS ON COST OF MAINTENANCE

To ensure the utmost economy in expenses of maintenance, none but the best procurable materials should be employed in the building of the motor vehicle, whether adapted for light or heavy duties. Steel enters very largely into the construction of motor vehicles for crankshafts, axles, springs, hollow shafts, tubes for framework, etc., and it is obvious that the best will in the long run be the most economical. The use of nickel steel, or, better still, of the new chrome vanadium steel, should therefore be insisted upon.

Chrome vanadium steel not only has a high tensile strength and high elastic limit, but also possesses resistance to torsion shock, and reversal of stresses, and is therefore most suitable for the work in question.

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THE END

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